SURVEY REPORT

(APPENDIXES)

GREEN RIVER WATERSHED

KENTUCKY · TENNESSEE

program for runoff and waterflow retardation - and soil erosion prevention

U. S. DEPARTMENT OF AGRICULTURE

MAY 1950

C O N T E N T S

Appendixes:

APPENDIX A

PHYSICAL FACTORS

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DESCRIPTION OF WATERSHED

General

The Green River Watershed (Figure A-1) comprises a total drainage area of approximately 9,273 square miles. This includes about 8,896 square miles in west-central Kentucky and 377 square miles in north-central Tennessee. From its source in Lincoln County, Kentucky, the river flows southwest for about 30 miles to the vicinity of Dunnville, Kentucky. Here the river turns westward and flows 200 miles in that direction to its junction with the Barren River. Downstream from this point the river follows the directional trend of the Barren and flows in a generally northwestern direction for 150 miles to its confluence with the Ohio River, 8 miles above Evansville, Indiana.

The entire Green River Watershed has been divided into two Physical Land Units, the Pennyroyal and the Western Coal Field, in order to develop and evaluate the proposed remedial program. These are major separations made on the basis of similarities with respect to vegetative cover, soils, geology, and stream characteristics within each of the two areas. These are important factors which influence runoff and flood control.

The upper 160 miles of the Green River is in the Pennyroyal. The lower 220 miles is in the Western Coal Field. The principal tributaries in the Pennyroyal are Robinson Creek, Russel Creek, Little Barren and Barren Rivers. Most of the Barren River tributary is in the Pennyroyal. The lower part is in the Western Coal Field. The upper part of the Nolin and Rough Rivers drainage areas is in the Pennyroyal. The principal tributaries in the Western Coal Field are Mud River, Rough River, Pond River, and Panther Creek.

Figure A-1 is a map of the watershed showing the Physical Land Units. They are described in the following discussion.

Pennyroyal Area

The Pennyroyal Area comprises 4,421 square miles or approximately 48 percent of the total watershed area. This Physical Land Unit is underlain by and its soils are derived from broadly similar limestone and shale formations, which have a regional dip to the west and northwest. For certain purposes of evaluation, the Pennyroyal was subdivided into, and basic data accumulated for its eastern and western sub-areas (Figure A-2).

The eastern sub-area, 29 percent of the total watershed, is underlain by limestones, cherty limestones, and shale. The topography is highly dissected, but there are limited ridge areas which have not been dissected. The soils are generally low-grade except for some of the ridge and bottom land areas. Surface drainage is dominant. Karst topography includes a small area. Thirty-three percent of the eastern sub-area is woodland.

The western sub-area, 19 percent of the total watershed, is underlain by limestones, cherty limestones and shale. Except for the more shaly portions stream drainage is absent, intermittent, or confined to larger streams which flow through the area. Karst topography and ground water drainage through solution channels are dominant. The soils are generally high grade including such series as the Hagerstown and Decatur. The topography is smooth to rolling. About 25 percent of this portion is woodland.

Western Coal Field Area

The Western Coal Field of Kentucky is part of a great synclinal structure (Eastern Interior Coal Basin) of Kentucky, Indiana, and Illinois. In the Green River Watershed, it includes 4,852 square miles or 52 percent of the total area. The shale and sandstone formations which underlie this have a general regional dip toward the center of the basin.

An important characteristic of the Western Coal Field is the broad alluvial valleys which comprise one-fifth of the total land area of this Physical Land Unit. Alluvial deposits in these valleys range up to 100 feet or more in depth and contain many "islands" of bed rock which are isolated during the higher floods. These alluvial deposits were probably laid down during the Wisconsin glacial epoch at a time when the Ohio River was draining the glacial occupied region. Aggradation and flooding of the Ohio at that time resulted in ponding of the Green and its lower tributaries. Alluvial deposits of the lower Green are partly normal material brought in from the headwaters and partly glacial material brought in by backwater.

For certain purposes of evaluation, the Western Coal Field was subdivided into, and basic data accumulated separately for the sandstone-shale and loess sub-areas (Figure A-2).

The sandstone-shale sub-area comprises 39 percent of the total watershed area. It includes the area where sandstone and shale formations outcrop or directly underlie surface soils formed from them residually. The eastern and southern margins of this sub-area have been thoroughly dissected by erosion. Some of the ridges are comparatively wide, as the one east of Leitchfield, Kentucky, but the majority are narrow and irregular. Valleys are entrenched and narrow along the eastern and southern margin but widen as the loess area is approached. Forest comprises 42 percent of this portion.

The loess sub-area comprises 13 percent of the total land area of the Green River Watershed. It includes the upland area where a loessial mantle overlies the sandstone and shale formations to depths which vary from four to twenty feet. The upland soils have been derived residually from this loessial mantle. This sub-area includes a large portion of the wide alluvial flood plains of the Physical Land Unit. Only 21 percent of the loess sub-area is in woodland.

The following table gives the areal distribution of Physical Land Units by states:

DISTRIBUTION OF PHYSICAL LAND UNITS BY STATES

Physical Land Unit	Kentucky	Tennessee	Total	Percent
	Acres	Acres	Acres	
Pennyroyal	2,587,939	241,501	2,829,440	47.68
Western Coal Field	3,105,280		3,105,280	52.32
Grand Total	5,693,219	241,501	5,934,720	
Total Square Miles	8,895.655	377.345	9,273	
Percent	95.93	4.07		100.00

LAND USE CAPABILITIES

Conservation surveys have been made in many areas of the Green River Watershed. These surveys show the different soil groups, the extent of erosion, and the relative steepness of the land. These physical factors determine the use suitability of the land or the Land Use Capability Classes.

Measured sample areas of conservation surveys were expanded to larger areas for which the individual samples are representative to determine the acreage of the different Land Use Capability Classes by present land use in the watershed. This information is shown in Tables A-1 and A-2.

RUNOFF

Under present land use conditions, runoff has been accelerated throughout the greater portion of the watershed. The infiltration rate and water storage capacity of the original soils have been decreased generally. An exceptional condition, where runoff has been retarded locally, is considered under the section on Karst Lands.

In order to consider how conversions of land use would be effective in reductions of runoff, changes to be made are listed in six broad categories as follows:

1. The remedial program would convert the larger portion of woodland in poor or medium hydrologic condition to good hydrologic condition. There is no woodland in good hydrologic condition under present conditions. A small portion of the woodland now in medium or poor hydrologic condition can be improved only slightly, or not at all. This is due to poor condition of the soil which may be the result of accelerated erosion or other modern causes, or may represent the original condition of the land.

2. All idle land would be converted to cropland, pasture, deep-rooted perennials, wildlife or woodland, according to its land use capability and needs.

3. All cropland of Capability Classes I, II, and III, and part of IV, will be retained as cropland, or converted to pasture, perennials or wildlife. Soil Conservation practices such as improved rotations, permanent vegetative strips and properly built terraces along with contour cultivation will improve the hydrologic condition of the land retained as cropland.

4. A part of Class IV cropland and all Class VI and VII cropland will be converted to pasture, perennials, wildlife or woodland.

5. Pasture improvement and management will improve the water retention capacity of pastured areas, thereby reducing runoff.

6. Miscellaneous areas consist of urban areas, roadways, railways, lakes, stream channels, farm home sites, etc. Except for stabilization of drainageways, cuts, and fills along roadways and railways, there will be little or no reduction of runoff from these areas.

Infiltration Formula Method

The infiltration formula method, which is based on data covering areas scattered over the entire United States, represents average conditions for the entire country. This has been devised to develop a simplified method to determine the effect of improved soil and cover conditions on runoff.

In applying this method it is necessary to have basic information of the soil and cover conditions for the watershed on which runoff determinations are to be made. Data were assembled, first, to show the distribution of soil textural groups by cover under existing land use conditions; and, second, to show the distribution of soil textural groups by cover after the remedial program is in full effect. The textural groups are based on field determination and/or mechanical analysis of sand, silt, and clay fractions. This is taken from tabulated data, published or unpublished for areas where soil surveys have been made. This classification is solely for use in the infiltration formula, and may group soils not similar in other respects. The extent of distribution of each group was based on measured soil conservation surveys or other types of measured soil surveys. The present cover distribution was based on soil conservation surveys, soil conservation district reports, and the U. S. Census of Agriculture. Future cover conditions, after the remedial program is in full effect, were based on the best conservation measures for the land as indicated by the land use capabilities and economic factors involved.

EROSION

The strata, which underlie the watershed, have for the most part a slight regional dip to the west and northwest. The sedimentary formations consist of limestones, cherty limestones, dolomites, sandstones and shale. A residuum, which ranges from less than two feet on steeper slopes to twenty-five feet on the flatter areas or more level ridges, has been formed in place by normal weathering processes. At some localities, the residuum itself may be covered by old stream terrace deposits, or as in the northwest portion of the Western Coal Field, have a loessial mentle which has been deposited upon the sandstone and shale residuum.

Residual soils which have been most severely damaged by modern erosion do not necessarily correspond to those where removals have resulted in the greatest flood plain damage by accelerated sedimentation. This is due to the fact that sand and coarser grained sediment, deposited in stream channels or on flood plains, cause the most severe sediment damage to valley farm lands.

Sheet Erosion

In areas where the original surface layer of the upland soils is fine grained, such as the silt loams, sheet erosion has caused damage to upland fields; but that portion of the topsoil removals, which is later deposited on alluvial lands, may be nearly as fertile as the soil on which it is deposited. In areas, however, where the surface soil contains considerable sand or gravel, rapid sheet erosion is likely to be followed by stream channel fill, if channel characteristics are favorable to aggradation or deposition of sterile sand or gravel on fertile flood plain soils.

The most extensive surface soils in the uplands of the Green River Watershed are the silt loams which comprise by land area 64 percent of the Pennyroyal and 29 percent of the Western Coal Field. These soils may or may not contain rock fragments such as chert or shale, depending upon the parent material or degree of weathering. Under original conditions, the surface silt loams are estimated to have averaged 6-10 inches in depth. The subsoil, where developed, is a silty clay loam, silty clay, or clay, ranging 0-30 or more inches in depth. It is estimated that the surface silt loam has been removed by sheet erosion from 25 percent of the Pennyroyal and 30 percent of the Western Coal Field, leaving subsoil exposed over this area. The upland loams and sandy loams comprise 2 percent by area of the Pennyroyal and 17 percent of the Western Coal Field. The last named textures generally occupy the rougher areas and are chiefly in woodland.

Gully Erosion

Acreages affected by deep gullies in need of stabilization are shown in Table A-3. The most severely gullied areas are in the Western Coal Field. These areas are particularly prominent in old fields having steep slopes in the sandstone-shale sub-area and throughout the loess sub-area. Due to the comparative shallow depth to bedrock, however, gullies do not present the problem in this watershed that

prevails in areas underlain by unconsolidated formations or loose weathered material to great depths. However, they are the source of some injurious sediment, and their stabilization is recommended as a land treatment measure.

Roadway and Railway

Roadway and railway cuts, fills, and drainageways constitute a source of erosional debris in the Green River Watershed. This is true in localities where loose, weathered material is exposed in cuts and where fills have not been stabilized by adequate water control structures and perennial vegetation.

SPECIAL PROBLEMS

Karst Lands

The various karst types and some of the problems which arise in farming the karst lands have been considered in an USDA publication by Dicken and Brown. 1/ The problems arise primarily from the fact that a subsurface drainage system was developed in pre-modern times, in the massive and soluble Ste. Genevieve and St. Louis limestone formations. These formations directly underlie the surface residuum in the western portion of the Pennyroyal. Along the eastern margin of the Western Coal Field, the Ste. Genevieve, or upper formation, is capped by the Cypress sandstone formation.

The karst land forms are variable in size and shape. They may vary from cistern sinks, a few feet in diameter, to large cave-in depressions which are commonly one-half mile or more in width and as much as 250 feet in depth. The plan may be circular, elliptical, or, irregular. The latter is the most common type. All have been formed by solution of limestone, or cave-ins due to solution of underlying limestone.

The concentric slopes draining into the resulting depressions have been severely eroded. While runoff must have been accelerated at first, blockage of the opening to subsurface channels, and colluvial deposits in the depressions have resulted in ponding of many of the depressions.

Approximately one-fifth of the Pennyroyal is drained entirely by subsurface or intermittent surface drainage. The areas so drained are concentrated chiefly in the western portion of that Physical Land Unit. A small part of the eastern margin of the Western Coal Field is drained by underground channels. This includes areas where percolation downward occurs through the fractured and permeable Cypress sandstone, or where the sandstone has caved due to undermining by solution of the Ste. Genevieve limestone.

1/ Dicken, S. N., and Brown, H. B., Jr., 1938. Soil Erosion in the Karst Lands of Kentucky, U. S. Dept. Agr., Soil Conservation Service, Circular No. 490, 62 pp. illus.

Many erosion control and runoff retarding measures that are effective in non-karst areas must be modified to be effective in karst areas. Due to the variance of karst land forms, each field presents its own peculiar problems. Adaptation of land use in this area requires special consideration of local conditions.

PRESENT LAND USE

Approximately 33 percent is woodland, 26 percent is cropland, 25 percent is pasture, 11 percent is idle, and 5 percent is miscellaneous. Eighty percent of the watershed is in farms. The remaining 20 percent of non-farm land is mainly woodland; but also includes urban areas, roadways, railroads, etc.

Of the land in farms, approximately 32 percent is cropland, 31 percent pasture, 22 percent woodland, 7 percent idle cropland, 6 percent abandoned idle, and 2 percent is occupied by farm sites. Corn and tobacco are the principal row crops. Tobacco occupies only about 5 percent of the cropland acreage but accounts for the largest single source of cash income. Most of the tobacco is Burley with smaller amounts of dark air cured and a very small amount of dark fire cured. Wheat occupies nearly three-fourths of the small grain acreage, the remainder being oats, barley, and rye. Of the total cropland, only about 10 percent has winter cover crop protection. The balance adds to the runoff and erosion problem. The pastures are generally overgrazed and need improvement. Most of the woodland is poorly managed. This contributes to the runoff problem.

CLIMATE

The climate is temperate. Average monthly temperatures vary from approximately 37° during January to 78° during July. The maximum recorded temperature at Bowling Green, Kentucky, is 113°, and the lowest, -17°. The average length of the growing season varies from 190 days in the southwestern part to 180 days in the northeastern part of the watershed.

Light snow and freezing temperatures occur annually over the entire watershed. The average annual depth of snowfall varies from 10 inches in the southwest to 20 inches in the northeast. Snow is seldom an important contributing factor to flood flows in the Green River Watershed. Frozen ground is, occasionally, an important factor in runoff. Occasionally, ice occurs on the Green River, or its tributaries.

Average monthly precipitation is well distributed throughout the year, but is generally greatest during the winter and early spring and least in late summer or early fall. The average annual rainfall for the entire watershed is about 46.5 inches, varying from 50 inches in the southern portion to 44 inches in the northern portion.

Flood producing storms generally originate over the Gulf of Mexico and pass over the watershed as they move toward the North Atlantic Coast. Precipitation occurs along the front of the disturbance due to the contact of the warm moist air from the south and a cold polar front advancing south from Canada. Floods generally follow a series of abnormally heavy rains which occur over a period of several days.

About 70 percent of the major floods occur during winter and early spring, and about 30 percent of the floods occur during the planting, growing, and harvest seasons. Floods in the latter group have lower stages, but because of the season of their occurrence, produce the most extensive crop damage.

CLASSIFICATION AND DETERMINATION OF WOODLAND HYDROLOGIC CONDITION

Hydrologic Condition Defined

Hydrologic condition is a measure of the ability of a vegetative cover-soil-use unit to retard runoff. As generally used, hydrologic condition is a relative term applied to a given cover-soil complex. The condition of this cover-soil association is based upon the effectiveness of the complex to retard runoff under a given use and treatment as compared to the degree of control obtained under the best type of use, but not necessarily under the optimum conditions to be obtained. Three classes of hydrologic condition--good, medium, and poor have been recognized in the Green River Watershed.

Hydrologic condition is a function of water movement, not of timber production. Contrary to popular belief, woodland having a satisfactory stocking of timber trees, and a high degree of crown canopy may not necessarily be satisfactory for watershed purposes. Frequently, woodland classed as "good" for timber management is actually doing a poor job in regulating water flow. Sometimes the forest soil in "managed" stands has deteriorated to the point where water absorption rates and water storage capacities are very low. On the other hand, certain "unmanaged," but protected woodland areas, although in "poor" condition from the viewpoint of the timber manager, may be in "good" condition from the standpoint of soil and water conservation and streamflow regulation. It is not to be construed, however, that all "managed" woodland is "poor" and that all "unmanaged" woodland is "good" for watershed purposes. Good forest management which recognizes all the resources of the forest land and their interdependence will produce forest conditions which are excellent for flood control as well as for timber production.

Criteria for Determining Woodland Hydrologic Condition

The relative hydrologic condition of any woodland may be determined from an examination of the forest soil, the forest floor, and the forest stand itself. There is a close relationship between the various humus types and their effect upon water movement and storage in soil. Hence, the humus of the forest soil is the best indicator of the watershed condition of a forested area. As the humus type varies with cover type and condition and is easily modified by such treatments as cutting, logging, fire, and grazing, the water relations of a forested area may also be determined from the cover type and its condition and treatment.

There are two major groups of forest humus, each of which consists of several types. In one major group, the organic matter is incorporated

with the mineral soil (mull humus), while in the second group the organic matter lies on the surface of the mineral soil (mor humus). Mull humus (organic matter incorporated with mineral soil) prevails in the Green River Watershed.

Mull humus is the A_1 horizon (surface layer unless eroded away) of the forest soil profile. The transition to the sub-soil is gradual, there being no definite line of demarcation between the A and B or A and C horizons. It may have a crumb-like structure and be loose, friable, and deep, or it may have a single-grained structure and be compact, firm, and shallow. The organic content per unit volume of humus varies according to type, from 2 to 60 percent. Mull humus is formed by the activities of soil fauna which feed upon vegetable debris of recent deposition (litter) and deposit their excrement in the soil or on the surface of the soil. The most important formers of mull humus are the earthworms (varying from the large night-crawlers to minute nematodes) and the myriapods (milipedes and centipedes). In addition to the excrement which these animals deposit within the soil, they condition the soil by providing pore space and water channels throughout that portion of the soil mass in which they are active. Frequently such channels extend to a depth of several feet. Large colonies of bacteria live in a supposedly symbiotic relationship to the fauna in the better types of mull humus. These bacterial colonies form minute masses of gelatinous material which is able to absorb and hold temporarily a considerable quantity of water.

The best humus type for watershed purposes is a mull type that has a crumb-like structure and is loose and friable. This "crumb" or "coarse mull" is formed by the large earthworms or in some cases by large milipedes. Under favorable conditions this type is formed rapidly. It frequently is built up at the rate of 1/10th inch per year, and in some situations as much as two inches may be formed in a 15-year period. The depth of this layer sometimes exceeds 18 inches. Earthworm activity in this type on the deeper soils has been observed at depths of several feet, extending well into the C horizon. Such forest soil has high infiltration capacities and percolation rates; and because of its high organic content (in the form of organic colloids), it is able to store temporarily a considerable amount of water. This humus type is characteristic of stands which have not been severely cut, heavily logged, burned, or grazed. Any treatment such as fire, grazing, over-cutting, or careless logging which exposes the forest floor to abnormally high temperatures, drying out, or compaction, kills or drives away the earthworms and mulipedes. Under such conditions, this desirable form of humus rapidly deteriorates and is changed to a less desirable type.

One of the poor humus types is also a mull. This humus, called "firm" mull, is single-grained, firm, compact, and tight. It is formed by those microscopic soil fauna which can exist under conditions unfavorable to the larger fauna. Although it may be formed rapidly from one of the better mulls which has been subjected to compacting treatment, this type grows at an exceedingly low rate, or in most cases remains static. It seldom attains a depth exceeding two inches. Firm mull contains very little organic matter, has very low infiltration capacities and percolation rates--at times being practically impermeable--

and has a low storage capacity. It is characteristic of heavily-cut, grazed, and burned woodland of all types.

Litter has several important functions in creating and maintaining good soil-water relationships. This material, composed principally of leaves, is a major food source for the humus-forming fauna. The blanket of leaves serves as an insulator against high temperature and evaporation which keeps the humus moist and cool so that the earthworms and associated fauna may thrive within it. This blanket also protects the humus from erosion by absorbing the force of water dripping from the canopy.

Earthworm occurrence is a good indicator of hydrologic condition. In general, the more abundant the worms, the better the soil-water relations in the area.

Sheet erosion is of common occurrence in woodlands subject to grazing. Gully erosion is present in several areas of steep terrain which have been logged by "up and down hill" skidding procedure. Any type of erosion, whether sheet or gully, is detrimental to good watershed conditions because it decreases to a minimum infiltration capacity, percolation rates, and storage capacity.

The size, age, and condition of the forest stand all serve as criteria for determining hydrologic condition. The canopy intercepts precipitation on its way to the ground, the amount intercepted varying according to the type and intensity of precipitation and the type and density of the canopy. Some of the intercepted water (or snow) evaporates (or sublimates), some of the water drips (or falls) through openings to the ground, but much of the water gets to the forest floor by flowing along the twigs, branches, and stems. Because this stemflow reaches the ground slowly, with little or no impact, it does not disturb the litter or the soil. Where an understory exists, the drip from the canopy falls on the lower vegetation and is disposed in a manner similar to that discussed for precipitation falling in the canopy. Thus, dense, several-storied forest stands are more desirable than open, single-storied ones for reducing the rate and force at which water reaches the ground.

Open forest stands, with thin canopies and little or no understories, afford the forest floor little or no protection from the wind. Wind is exceedingly harmful because (1) it disturbs and causes a poor distribution of litter, and (2) it dessicates the soil. Stands with dense canopies and having a well-distributed understory protect the forest floor from the wind. This protection keeps the litter from blowing about and prevents the drying out of humus.

A major function of forest cover in flood control is to increase the storage capacity of the soil mantle by pumping out water during the process of transpiration. As well-stocked stands of larger timber transpire more water than understocked or young stands, they are more effective in maintaining a high degree of storage capacity within the soil mantle.

The criteria for determining the hydrologic condition of the woodland in the Green River Watershed are listed in Table 1.

Hydrologic Condition of Present Woodland

The hydrologic condition of the present woodland was determined from approximately 2,000 one-acre samples, 50 percent of which were forest survey plots. The forest survey plot-cards contained sufficient information to segregate the plots in poor condition from those in medium and good condition. The remaining samples were examined stereoscopically for crown density, stocking, and erosion for extracting the plots in poor condition from the others. The hydrologic condition of the plots other than those designated as poor was questionable. Consequently, 10 percent of these were examined in the field to determine their condition. The samples were expanded and summarized as shown in Table 2. None of the woodland is in good hydrologic condition, 10 percent is in medium condition, and 90 percent is in poor hydrologic condition.

The causes for the generally poor hydrologic condition are overcutting, grazing and fire. Overcutting and grazing are the principal abuses to which the woodland has been subjected. Approximately 90 percent of the woodland has been overcut, 80 percent grazed, and 65 percent burned.

Derivation of Hydrologic Condition of Future Woodland

The hydrologic condition of woodland under the proposed program was estimated according to the following reasoning.

With accelerated education and incentive payment programs, it is assumed that all of the land operators and owners will participate 100 percent in the proposed program. This will practically eliminate pasturing of woodland and overcutting, and will considerably reduce woods burning.

Because some fires are accidental, it is to be expected that some of the woodland will be burned--even where it is afforded a high degree of protection. The aim of this program, as designated for flood control purposes, is to have no more than 5 percent of the woodland area in poor condition because of fire. Thus of every 100 acres of woodland, no more than 5 acres would always be in poor condition because of burning. Observations indicate that it will require approximately 50 years for badly burned areas to recover to the extent that they can enter the "good" hydrologic condition class. 1/ Many fires occur on previously burned areas, but to be conservative in estimating the flood flow reductions to be obtained under the program, it must be assumed that each fire occurs on an area not previously burned.

1/ "Good" hydrologic condition is not necessarily the optimum condition to be obtained. In many wooded areas which have been burned repeatedly, optimum conditions may not be obtained for 100 years -- in some stands longer. In other areas burned but lightly, recovery may occur in 15 to 20 years.

It is estimated that 5 percent of the woodland recovering from burning will be in the medium hydrologic condition class. It is further estimated that an additional 10 percent of the woodland, recovering from logging operations, will be in medium hydrologic condition.

Based on these assumptions, it is estimated that the hydrologic condition of the future woodland will be distributed as follows:

Good	80 percent
Medium	15 percent
Poor	5 percent

These values were applied to the planned woodland area to yield the estimated future hydrologic condition as given in Table 2.

Table A-1

DISTRIBUTION OF LAND IN THE PENNYROYAL PHYSICAL LAND UNIT
SHOWING PRESENT LAND USE BY LAND USE CAPABILITY CLASSES
GREEN RIVER WATERSHED

Land Use Capability Class	Present Land Use (Acres)				Total
	Cropland	Woodland	Idleland	Pasture	
I	50,207	9,820	843	11,626	72,496
II	355,612	134,925	34,950	208,268	733,755
IIA	44,639	21,305	7,871	34,094	107,909
III	188,762	145,235	53,825	191,588	579,410
IIIA	13,769	19,608	9,083	15,281	57,741
IV	72,942	120,792	52,357	157,351	403,442
IVA	4,964	18,803	3,355	6,644	33,766
VI	28,074	137,150	50,392	125,075	340,691
VII	12,863	231,312	26,446	83,450	354,071
Sub-total	771,832	838,950	239,122	833,377	2,683,281
Misc. 1/					146,159
Total					2,829,440

1/ Includes urban areas, roadways, railways, lakes, stream channels, farm home sites, etc.

Table A-2

DISTRIBUTION OF LAND IN THE WESTERN COAL FIELD PHYSICAL LAND UNIT
SHOWING PRESENT LAND USE BY LAND USE CAPABILITY CLASSES
GREEN RIVER WATERSHED

Land Use Capability Class	Present Land Use (Acres)				Total
	Cropland	Woodland	Idleland	Pasture	
I	18,133	1,158	271	7,178	26,740
II	153,711	38,106	36,717	119,004	347,538
IIA	200,022	121,827	48,917	48,751	419,517
III	219,839	59,695	57,843	178,403	515,780
IIIA	22,647	27,220	7,635	8,080	65,582
IV	70,938	41,501	50,353	99,904	262,696
IVA	1,226	745	741	--	2,712
VI	16,899	39,188	14,667	29,814	100,568
VII	57,291	817,138	167,134	172,251	1,213,814
Sub-total	760,706	1,146,578	384,278	663,385	2,954,947
Misc. 1/					150,333
Total					3,105,280

1/ Includes urban areas, roadways, railways, lakes, stream channels, farm home sites, etc.

Table A-3

DISTRIBUTION OF DEEP GULLIES IN GREEN RIVER WATERSHED
(NEEDING STABILIZATION)

Physical Land Units	Less Than 3 Per Acre	More Than 3 Per Acre	Total Area Affected	Total Land Area
Pennyroyal	46,470 acs.	7,807 acs.	54,277 acs.	2,829,440 acs.
Western Coal Field	121,705 acs.	73,113 acs.	194,818 acs.	3,105,280 acs.
Total	168,175 acs.	80,920 acs.	249,095 acs.	5,934,720 acs.

Table A-4

CRITERIA FOR DETERMINING HYDROLOGIC CONDITION OF WOODLAND
GREEN RIVER WATERSHED

Cover and Soil Factor	Hydrologic Condition Class		
	Good	Medium	Poor
Humus (A_1 Horizon)			
Type	Coarse to Fine Mull	Coarse to Fine Mull	None or Firm Mull
Consistency	Friable	Slightly compact	Compact
Depth	4 inches or more	2-4 inches	Less than 2 inches
Distribution	100%	100%	100% or less
Litter Distribution	100%	90%-100%	Less than 90%
Soil Erosion, Sheet or Gully	None or recovery complete	Arrested	Active
Earthworm Occurrence	Abundant	Moderate	Few to none
Forest Stand			
D.B.H., inches	16 +	10-16	Under 10
Age class	All-aged	All- or even-aged	All- or even-aged
Crown Canopy, Density	90%-100%	70%-90%	Under 70%
Understory, Density	90%-100%	70%-90%	Under 70%
Vigor	Thrifty	Thrifty	Unthrifty

Table A-5

AREA OF WOODLAND BY HYDROLOGIC CONDITION CLASSES
AND PHYSICAL LAND UNITS,
WITH AND WITHOUT A REMEDIAL PROGRAM
GREEN RIVER WATERSHED

Physical Land Unit	Hydrologic Condition Class							
	Without Program (Present)				With Program (Future)			
	Good	Medium	Poor	Total	Good	Medium	Poor	Total
	Acres	Acres	Acres	Acres	Acres	Acres	Acres	Acres
Western Coal Field	0	114,658	1,031,920	1,146,578	1,032,985	193,685	64,562	1,291,232
Pennyroyal	0	83,895	755,055	838,950	688,186	129,035	43,012	860,233
Watershed Total	0	198,553	1,786,975	1,985,528	1,721,171	322,720	107,574	2,151,465

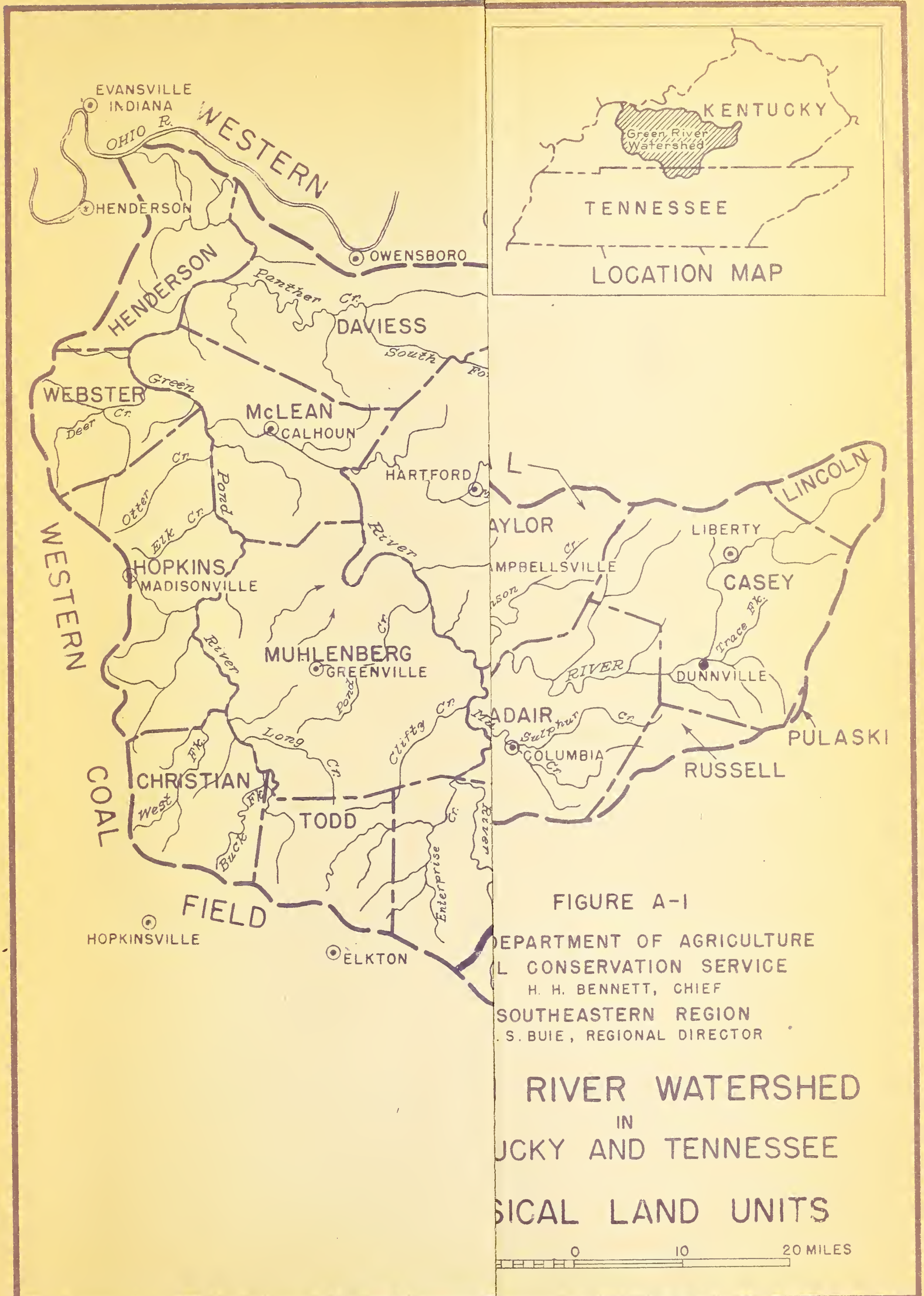

FIGURE A-1

EPARTMENT OF AGRICULTURE
L CONSERVATION SERVICE
H. H. BENNETT, CHIEF
SOUTHEASTERN REGION
. S. BUIE, REGIONAL DIRECTOR

RIVER WATERSHED
IN
UCKY AND TENNESSEE

SICAL LAND UNITS

2-N-6145D-3

FIGURE A-1

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
H. H. BENNETT, CHIEF
SOUTHEASTERN REGION
T. S. BUIE, REGIONAL DIRECTOR

GREEN RIVER WATERSHED
IN
KENTUCKY AND TENNESSEE
PHYSICAL LAND UNITS

2-N-6145D-3

FIG. A-2

PARTMENT OF AGRICULTURE
CONSERVATION SERVICE
H. H. BENNETT, CHIEF
OUTHEASTERN REGION
. BUIE, REGIONAL DIRECTOR

RIVER WATERSHED
IN
CKY AND TENNESSEE
SHOWING
CAL LAND UNITS

2-N-6145D-5

FIG. A-2

FIG. A-2
U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
H. H. BENNETT, CHIEF
SOUTHEASTERN REGION
T. S. BUIE, REGIONAL DIRECTOR

GREEN RIVER WATERSHED IN KENTUCKY AND TENNESSEE SHOWING PHYSICAL LAND UNITS

2-N-8145D-5

APPENDIX B

LAND AND WATER ECONOMY

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LAND AND WATER ECONOMY

Area and Population

Of the 34 counties in the states of Kentucky and Tennessee which will be directly affected by the recommended watershed treatment program 31 are in Kentucky and 3 in Tennessee. Twelve of the Kentucky counties lie entirely within the Green River Watershed. The 3 Tennessee counties and 19 of the Kentucky counties are only partially within the watershed.

The total land area of the watershed is approximately 5,934,720 acres, or 9,273 square miles. The total population of the watershed at the time of the 1940 Census was about 434,000 people. Of the 1940 population, approximately 415,000 were residents of Kentucky, and about 19,000 were residents of Tennessee. On a proportionate basis Kentucky has 96 percent of the total watershed area and 96 percent of the population, while Tennessee has 4 percent of each.

In 1940 approximately 90 percent of the Green River Watershed population was rural in character. A study of the 1945 Census of Agriculture indicates that over 210,000 people in the Green River Watershed lived on farms at the beginning of 1945. The total population of the watershed in 1930 was about 425,000. Compared to the population for 1940, an increase of 9,000 people is indicated, or about 2 percent. In the meantime, the relation between rural and urban populations in the watershed changed from 9 percent urban in 1930 to 10 percent urban in 1940.

There are no large urban centers in the Green River Watershed. Bowling Green, Kentucky, with a population in 1940 of less than 15,000, is the largest city in the watershed. There were only three urban centers in the watershed with populations in excess of 5,000 in 1940. However, by 1950, the rapid growth of Elizabethtown, Kentucky, has undoubtedly placed it in the population class of 5,000 or over. Both Bowling Green and Elizabethtown are within the Pennyroyal limestone soil province.

The Mammoth Cave National Park is the only publicly-owned land in the Green River Watershed of any appreciable size. It is located in Hart and Edmonson Counties and comprises an area of approximately 50,600 acres. Its maximum area was set by Congress at 70,618 acres.

The first settlers entered this region about 1775. After 1780 there was a general movement westward from the first settlements along the woodland fringe of the Barrens. At this time there was a rapid increase in population and a progressive opening of the Western Kentucky Coal Field region. The wild grass lands of the Barrens were soon stocked with livestock, and cleared tracts were used for corn, wheat, hemp, hay, and vegetables for home use.

The early settlement of this watershed was not directed toward the main stems of the major streams, as in some watersheds. Instead of the major streams setting the pattern of settlement, in the Green River

Watershed, the pattern and density of settlement caused the waterways to become important as arteries of commerce and travel. The first waterway improvement for navigation was undertaken about 60 years after the first settlers entered the watershed.

Agricultural Resources

Agriculture accounts for the major portion of the occupational activity in this watershed. There are some relatively small, localized, areas within the watershed where mining is of more importance than agriculture. For example, coal mining is of major importance in an area centering around Central City, Kentucky, within the Western Coal Field soil province. Near Kyrock, Kentucky, the mining of rock asphalt accounts for the major portion of the occupational activity. But, these examples are, relatively speaking, not numerous when compared to the areas in which farming is of major importance.

Tobacco is the predominant cash crop in the watershed at present. Of the open land in the watershed, pasture crops occupy by far the largest acreage. On an acreage basis, corn is next in importance, hay crops are third, and small grain fourth. The present gross farm income, at 1948 prices, exceeds 133 million dollars.

Due to the wide variations in soil and topography and the corresponding variations in the types and systems of farming between the two major areas and their subdivisions, they will be considered separately.

Pennyroyal Area

This division of the watershed, approximately 2,829,440 acres in extent, is principally comprised of limestone and shale soils. The greatest consistent differences in the types and systems of farming within this area are due to variations in topography and inherent soil fertility. For land use and economic evaluation purposes, this area has been subdivided into two parts.

The Western Pennyroyal sub-area, approximately 1,140,870 acres in extent, includes extensive areas of smooth, moderately high grade limestone soils. Its topography is probably best described as ranging from smooth to rough. Approximately 84 percent of the Western Pennyroyal is farm land. The greater portion of the non-farm land is public and private non-farm woodland.

The farms in the Western Pennyroyal sub-area averaged approximately 100 acres in size in 1945, being some larger as an average, than in any other part of the Green River Watershed. They are principally owner-operated farms. Tobacco is the most important cash crop. Tobacco and livestock are the most important sources of cash farm income, being about equal in importance. The four major crops in order of gross value at 1948 prices are pasture, tobacco, grain crops (principally corn), and hay. About 15 percent of the farm land is farm woodland, 33 percent is in harvested crops, and 42 percent is open pasture. The other 10 percent is miscellaneous farm land, cropland idle or fallow, and crop failure. For the 1944 crop

year (1945 Census), the percent crop failure was lower for this area than for any other in the watershed. Of the harvested cropland approximately 62 percent is planted to clean cultivated row crops.

The importance of flood plain land in the Western Pennyroyal is relatively small.

The Eastern Pennyroyal sub-area, about 1,688,570 acres in extent, is principally one of rough topography and low grade limestone and shale soils. However, there are some small areas of smooth, moderately high grade limestone soils scattered throughout this part of the watershed. This sub-area also embraces a relatively narrow, irregular band of low, round-topped hills, known as the Knobs. The Knobs are located along the northeastern boundary of the watershed.

About 86 percent of the Eastern Pennyroyal sub-area is in farms. The average farm is somewhat smaller than in the Western Pennyroyal. The farms average slightly over 80 acres in size, and are principally owner-operated. The principal source of cash income is tobacco. Livestock is second in importance. The four major crops in order of gross value at 1948 prices are tobacco, grain crops (principally corn), pasture, and hay and seed crops. Over 26 percent of the farm land is farm woodland, 31 percent is harvested cropland, and 30 percent is open pasture (most of which is cropland pasture). The remaining 13 percent is miscellaneous farm land, cropland idle or fallow, and crop failure. Of the harvested cropland about 64 percent is planted to clean cultivated row crops.

The importance of flood plain land in the Eastern Pennyroyal sub-area is some greater than in the Western Pennyroyal, but is still of minor importance in relation to the total land area. About 60 percent of the open flood plain land is used for corn production. The other 40 percent is used primarily for pasture, hay and seed crops. In some of the rougher parts of the Eastern Pennyroyal, particularly in the vicinity of the Knobs, some tobacco is found in the flood plain. An example of this is found in Casey County, Kentucky, near the source of Green River, where some of the burley tobacco crop is planted in the flood plain of Green River. Tobacco is also grown in the flood plain of Robinson Creek in Taylor County, Kentucky, as well as along other tributary streams in this vicinity. For the entire Pennyroyal area, tobacco accounted for less than one percent of the open flood plain land. However, due to its high damageable value and susceptibility to flood damage, one percent of burley tobacco in the flood plain is roughly equivalent to 10 percent corn in the amount of damage incurred from summer season floods.

Western Coal Field Area

This area includes some 3,105,280 acres of the Green River Watershed, a little over 52 percent of the total watershed. Due to the heterogeneous nature of the area it has been subdivided into two parts for the purpose of economic evaluation.

The Sandstone-Shale sub-area is approximately 2,336,150 acres in size. Its topography is generally rough, but varies considerably from east

to west. Along the eastern rim of the area the topography is extremely rough and precipitous with narrow valleys and very little bottom land. This section of the Sandstone-Shale area is principally wooded. There is very little agricultural activity in this part of the area, most of which is transition material but which also includes a narrow neck known as Brush Creek Hills. The Mammoth Cave National Park is located in the transition area.

The western part of the Sandstone-Shale sub-area is not so rough, having extensive areas of low, rolling hills and relatively wide valleys.

Approximately 73 percent of the Sandstone-Shale sub-area is farm land. The average size farm is about 98 acres; of which 26 percent is farm woodland; 28 percent is harvested cropland; 28 percent is open pasture; and 18 percent is miscellaneous farm land, cropland idle or fallow, and crop failure. About 63 percent of the harvested cropland is planted to clean cultivated row crops.

Tobacco is the major cash crop in this area, but livestock is the largest source of cash farm income. The four major crops in order of gross value at 1948 prices are pasture, grain crops (principally corn), tobacco, and hay crops. Subsistence and part-time farms are more numerous in this area than in other parts of the watershed.

Flood plain land is of considerable importance in the Sandstone-Shale sub-area. The rough topography and generally low grade soils found in the upland parts of the area emphasize the importance of the bottom land. Approximately 10 percent of the area is alluvial soil. The present use of the open flood plain land is approximately 60 percent corn, 10 percent soybeans for beans, and 29 percent pasture and hay crops, with only 1 percent reported as idle.

The Loess sub-area, approximately 769,130 acres in extent, is a fairly homogeneous section of low hills and exceptionally broad bottoms. It is also known as the Lower Green River Valley. Farm land accounts for about 83 percent of its area. The average size farm is approximately 95 acres; of which about 10 percent is farm woodland; 43 percent is harvested cropland; 27 percent is open pasture; and the remaining 20 percent is miscellaneous farm land, cropland idle or fallow, and crop failure. Tobacco is the major cash crop, but, as a source of cash farm income, it is about on a par with livestock. About 63 percent of the harvested cropland is planted to clean cultivated row crops.

In order of gross value at 1948 prices the four major crops are grain crops (principally corn), tobacco, pasture, and hay crops.

Nearly half of this area is flood plain land. Due to the extensiveness of the alluvial soils in the Loess area, about the same land use prevails in the flood plain as for the area as a whole.

Industry

There are no large commercial centers within the Green River Watershed. Bowling Green, Kentucky, the largest town in the watershed, is principally an agricultural center.

The principal industries are mining, production of oil and gas, manufacture of timber products, tile, and brick. Important resources are coal, rock asphalt, timber, oil, gas, and commercial stone.

Ownership of Farmland

The farm ownership pattern in this watershed is not expected to be an adverse factor affecting a flood control program in the Green River Watershed.

Because of the large proportion of resident owners and high percent of operators residing on farms, farm tenancy is not likely to affect the progress of the remedial program. Also, farm tenancy decreased rapidly during the period 1940 to 1945 (Table B-1).

The program is expected to have little effect upon ownership or tenancy of farms, since there will not be any radical changes in the general type of farming within the watershed.

Ownership of Woodland

Ownership of woodland must be considered in developing the woodland phase of the remedial program for flood control purposes. The amount of participation and the cost of certain remedial measures will vary according to the type of ownership. Four general classes of woodland ownership are recognized in the Green River Watershed. These are Federal, non-Federal Public, Private farm, and Private non-farm. The distribution of these lands is shown in Table B-2.

The only Federal woodland now in the watershed is that in the Mammoth Cave National Park. This is non-commercial woodland. The amount of Federal woodland will be increased through acquisition. These lands may be considered as being in full participation in the program, since their purchase will depend upon the inability of the private owners to participate. Although these acquired lands will be consolidated and their area will be relatively large, the cost of managing and protecting them will be somewhat higher than on non-Public land. This is due principally to the critical condition of the woodland. The management and protection of these lands probably will influence considerably the treatment given to nearby privately owned woodland.

There are no state forests in the watershed. The non-Federal Public woodlands are for the most part in small holdings such as occur around reservoirs and adjacent to other property under the same ownership. As public lands, they may be considered to be in complete participation in the proposed program. Because such holdings are small and

scattered it is expected that the cost distribution for program measures will differ from that on either Federal woodland or Private woodland.

It is expected that the owners of Private woodland, farm and non-farm will participate to the same extent because both will be accorded the same treatment under the program. An incentive will be given the owners by technical advice and assistance, adequate protection of their woodland from fire, and incentive payments for forest planting.

Legislative Factors

The states of Kentucky and Tennessee have adopted and incorporated into their respective state statutes soil conservation district laws. More than 90 percent of the total watershed lands are in active soil conservation districts. These districts will augment the application of recommended remedial measures.

The Kentucky Department of Conservation through its Division of Soil and Water Resources is authorized to acquire and to make available to soil conservation districts heavy or specialized machinery or equipment which an individual district cannot itself economically obtain. The Department, through its Flood Control and Water Usage Board, also makes studies and recommendations as necessary to establish a state-wide program of flood control. The Board reviews, for the state, all survey reports, engineering reports, and other reports concerning projects within the state related to flood control and the usage of water resources.

The Weeks Act of 1911 and the Clarke-McNary Act of 1924 provide for Federal acquisition for watershed protection, provided the states consent to such acquisition. Kentucky has passed enabling legislation for Federal acquisition. However, the Flood Control Act of 1944 requires specific enabling legislation by the states for land acquisition for flood control purposes. Kentucky has not passed such legislation because no specific cases have previously arisen in that State.

The Fulmer Act of 1935 provided for state ownership of forest lands acquired from Federal funds. However, this act has never been activated.

The Clarke-McNary Act of 1924 provides for Federal-state cooperation on a fund matching basis in fire control and forest planting. The Norris-Doxey Farm Forestry Act of 1937 provides for Federal contributions to the states for technical assistance to woodland owners in woodland management including planting and silvicultural treatment; protection; and the harvesting, utilization, and marketing of forest products; and to enter into cooperative agreements for the establishment and care of farm or other forest-land tree and shrub plantings. The States of Kentucky and Tennessee are actively cooperating with the Federal Government in the activities authorized by these laws. This forms an excellent basis for expediting the woodland phase of the remedial program.

A supplement to the Clarke-McNary Act of 1924 (Public Law 392, 81st Congress) authorizes the intensification of Clarke-McNary activities by other programs when the Clarke-McNary program is inadequate to accomplish the objectives of these programs.

Drainge Enterprises

There are about 90 drainage enterprises in the Green River Watershed. The majority of these enterprises are located in the Loess sub-area of the Western Coal Field area. These works represent a capital investment of approximately $2,273,000 and affect an area of some 241,500 acres.

Some of these organizations have been more or less inoperative during recent years. It is anticipated that there will be a resumption of drainage activities in the watershed when the flood control remedial program is initiated.

Table B-1

FARM TENANCY IN THE GREEN RIVER WATERSHED 1/

Area 2/	Percent of Farm Operators Who Were Tenants	
	1940 (Percent)	1945 (Percent)
Pennyroyal	35.1	23.7
Western Coal Field	32.2	23.3
Green River Watershed	33.7	23.5

1/ From U. S. Census of Agriculture, 1945, Vol. 1, Parts 19 & 20, U. S. Department of Commerce, Bureau of Census.

2/ The percentages for each area are weighted averages based on the proportion of each county within a given area.

Table B-2

Physical Land Unit and State	rogram			
	Feder		Private 1/	Total
	Acres		Acres	Acres
Western Coal Field				
Kentucky	45,000		805,766	1,291,232
Sub-Total	45,000		805,766	1,291,232
Pennyroyal				
Kentucky	--		766,187	768,181
Tennessee	--		92,052	92,052
Sub-Total	--		858,239	860,233
Watershed Total	45,000		1,664,005	2,151,465

1/ Not distributed between far urposes is unknown.

Table P-2

WOODLAND OWNERSHIP WITHOUT AND WITH A REMEDIAL PROGRAM
GREEN RIVER WATERSHED

Physical Land Unit and State	Without a Program					With a Program			
	Public		Private			Public			
	Federal	Non-Federal	Farm	Non-Farm	Total	Federal	Non-Federal	Private 1/	Total
	Acres	Acres	Acres	Acres	Acres	Acres	Acres	Acres	Acres
Western Coal Field									
Kentucky	45,000	1,666	504,795	595,117	1,146,578	483,800	1,666	805,766	1,291,232
Sub-Total	45,000	1,666	504,795	595,117	1,146,578	483,800	1,666	805,766	1,291,232
Pennyroyal									
Kentucky	--	1,994	471,521	286,29[illegible]	759,813	--	1,994	766,187	768,181
Tennessee	--	--	54,576	24,561	79,137	--	--	92,052	92,052
Sub-Total	--	1,994	526,097	310,859	838,950	--	1,994	858,239	860,233
Watershed Total	45,000	3,660	1,030,892	90[illegible],976	1,985,528	483,800	3,660	1,664,005	2,151,465

1/ Not distributed between farm and non-farm because proportion of land to be acquired from each for flood control purposes is unknown.

APPENDIX C

HYDROLOGY

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PROCEDURES FOR CALCULATING FLOOD REDUCTIONS

Hydrologic investigations were made to determine the flood reductions which might reasonably be expected as a result of the recommended program. The determination of present and future damages and benefits (before and after the program) was in general made separately for the tributaries and for the reaches of the main streams of the Green River. The hydrologic investigations followed this same breakdown, but by far the larger part of the work was done on the tributary investigation, since the greater part of the benefits is to be expected on the tributaries.

TRIBUTARIES

The Green River drainage area was divided into "Physical Land Units" which, under similar cover and treatment, produce fairly uniform runoff, sediment, and deterioration of soil resources. Sample tributaries were selected to represent these physical land units. (See Figure C-1.)

The Green River Watershed was divided into two Physical Land Units -- the Pennyroyal and the Western Coal Field. One sample tributary was selected in each Physical Land Unit.

Description of the Sample Tributaries

1. Barren River above the gage near Pageville, Kentucky, was selected to represent the tributaries in the Pennyroyal Physical Land Unit. This sample tributary is a large one, containing 535 square miles. It is roughly rectangular in shape (about 25 miles east and west by about 21 miles north and south), with the gage at the northwest corner. (See Figure C-1.)

The watershed lies from about 500 feet to about 1500 feet above sea level, with a considerable area above the 900-foot elevation. The stream profile goes to about 950 feet above sea level, near the headwaters. The lower forty percent of the stream length is comparatively flat, with an average slope of 2.5 feet per mile. The middle forty percent has a slope of about 8.0 feet per mile, while the headwaters are much steeper, averaging nearly 60 feet per mile. The topography of the upper reaches is rough.

The drainage pattern is semi-fanshaped above the gage, long tributaries coming in on both sides of the stream with several of them joining the main stream fairly close together at a point about twenty miles above the gage. Another fanshaped area of considerable size converges about the middle of the western boundary line of Monroe County, Kentucky.

2. Pond River above the gage near White Plains, Kentucky, was selected to represent the tributaries in the Western Coal Field Physical Land Unit. This is a moderately large sample tributary, with a drainage area of 324 square miles. It is roughly square to irregular in shape, with the gage at the northern extremity.

The watershed lies from about 350 feet to about 750 feet above sea level, with a large area above the 500-foot elevation. The stream profile itself goes to over 600 feet above sea level near the headwaters. The lower eighty percent of the stream length is flat, with an average slope of about 1.5 foot per mile. The upper reaches are considerably steeper, averaging about 18 feet per mile.

The drainage pattern above the gage is dendritic and roughly triangular in shape. Tributaries are quite large and are on both sides of the main stream, but in general enter the main stream at rather widely separated distances.

Since the stream-flow record at the White Plains gage was short, it was supplemented for hydrologic purposes by the gage higher up on Pond River near Apex, Kentucky. This drainage area is much smaller (196 square miles) but of roughly similar shape to the White Plains drainage area. The zero of the Apex gage has an elevation of over 390 feet, so that practically all of the drainage area above Apex is over 400 feet above sea level. The drainage pattern above Apex is semi-fanshaped, tributaries from each side nearly meeting here.

Precipitation and Stream-flow Data: Availability and Average Values

Long-term records of daily rainfall from standard U. S. Weather Bureau depth-of-precipitation gages were reasonably plentiful over the Green River Watershed as a whole. However, precipitation stations for use in the analysis of the sample tributaries were rather scanty in number and not adequate for best results. There was in particular a lack of records showing the rainfall in the upper reaches of the sample tributaries. (See "Railfall versus Runoff and Peak Stage Relations" for more details.)

Average annual rainfall over the watershed as a whole is about 46.5 inches, with a considerably greater average at nearly all the long-term stations in the middle and upper reaches of the area.

Stations with a record of over 50 years are:

Bowling Green, Kentucky (68 years, 48.8 inches),
Greensburg, Kentucky (62 years, 48.3 inches),
Hopkinsville, Kentucky (54 years, 47.0 inches),
Leitchfield, Kentucky (55 years, 47.7 inches),
St. Johns, Kentucky (53 years, 46.2 inches).

Other long-term stations are:

Brownsville, Kentucky (33 years, 50.0 inches),
Celina, Tennessee (46 years, 51.4 inches),
Greenville, Kentucky (34 years, 46.9 inches),
Russellville, Kentucky (40 years, 45.1 inches).

As shown in Figure C-1, these long-term stations happen to be mostly in the middle and upper portions of the watershed, where the average annual rainfall is in general above the watershed average.

No intensity-of-precipitation records of any length were available in the watershed itself. Some of the "Hydrologic Network" stations might be used for short-term intensity studies, although the published data is not sufficient for making the analysis leading to a "dimensionless diagram", since nothing less than hourly intensities are being published. Louisville, Kentucky, and Lexington, Kentucky, are first-order stations, but are considerably north of the watershed, in an area of lower average annual rainfall (about 43.4 inches per year), so that they are not suitable for use in the Green River analysis. See "Analysis of Intensity of Precipitation Records" for more details.

Stream-flow records were in general available where needed, although some difficulty was encountered in the analysis for the Pond River sample tributary. See "The Evaluation Series of Floods."

Average annual runoff is about 18 inches per year over the middle and upper portions of the watershed, varying from about 17 inches in the middle portions to about 20 inches in the headwater portions. See the recent U. S. Geological Survey publication: "Annual Runoff in the United States" (Circular 52, 1949).

Outline of the Procedure for Evaluating the Recommended Program

The major phases of the procedure used to evaluate the effect of the recommended program on each sample tributary and to expand these data to the physical land units are briefly outlined below.

1. Rainfall (P) versus runoff (Y) relations were developed for each sample tributary using actual stream-flow and precipitation records.

2. An evaluation series of floods was developed for each sample tributary.

3. The effect of infiltration of rainfall into the soil, both before and after the proposed land use program, was determined by a simplified method using an empirical formula. Local soil, cover, and hydrologic conditions were taken into account by the use of special coefficients in the general formula. The major steps used in the application of the formula are:

   a. Use was made of an analysis of the best available record from a recording gage (intensity of precipitation data) typical so far as possible of the whole watershed.

   b. The soils in the watershed were classified as to texture, and the area of each texture group determined for each physical land unit and each sample tributary.

c. Cover conditions were classified in accordance with the classification set up by the coefficients used in the infiltration formula. This in combination with the soil classification of (b) above gives the evaluation classes used in this phase of the investigation.

d. The area of each evaluation class in each sample tributary was determined and listed, for both present conditions and future conditions (after land treatment measures have been applied).

e. An index (Θ) was computed for each evaluation class in each sample tributary using the infiltration formula and the average rainfall versus runoff relation of 1 above. This index, expressed in inches per hour, is the average infiltration rate and was adjusted to conform to the measured P versus Y relation.

f. Using these values of Θ and the area of each evaluation class (both present and future) computed storm runoffs (P_e) were determined for each evaluation class and for the whole sample tributary for each of the selected average storms. This gave P versus P_e relations for the sample tributary for both present and future.

4. Studies were made of all floods in the evaluation series to determine the reduction in peak gage heights that would result from channel improvement.

5. Peak stages for future conditions were determined. See "Effect of the Recommended Program on Flood Reductions."

6. The areas inundated by a flood of a given peak gage height (from "bankfull stage" to the highest peak considered possible) were determined from actual engineering field surveys combined with a stereoscopic study of the corresponding aerial maps. With this information it was possible to estimate the flood damages over the period covered by the evaluation series of floods.

Each of the steps in the above list is explained more fully in the following sections.

PRESENT STORM DISCHARGE

Rainfall versus Runoff Relations

Rainfall versus runoff relations were developed for each sample tributary, using all available stream-flow and precipitation data.

Depth of rainfall (P) for each storm was computed using the Horton-Thiessen method for determining the weights of the recorded precipitation. (See Table C-1 for the weights used.) In this survey it was found that consideration of "antecedent rain" was advisable, as trial showed that the rainfall corrected by adding an "index of antecedent rain" to the actual storm rainfall gave more consistent results than the storm rainfall alone. The index used was the customary one, defined by:

$$\underline{\text{Index}} = P_1/1 + P_2/2 + P_3/3 + \ldots + P_{10}/10,$$

where P_1 is the rain, in inches, falling on the day preceding the first day of the storm rainfall, P_2 the rain falling during the second preceding day, etc. Whenever antecedent rain was used in the investigations it was used consistently throughout both present and future so that a true comparison could be made.

Total discharge was computed using the observed discharge hydrographs for the storm periods, as plotted from stream-flow data. Ground-water inflow into the stream was determined by a simplified method based on the ground-water depletion curve. Total discharge during the storm period, less ground-water inflow, gave the "storm discharge" (Y). These computations were made for each storm, for which data were available, occurring in the evaluation series. The results were plotted for each sample tributary as a "scatter diagram" and an average P versus Y relation determined graphically from this diagram. Seasonal relations were not used, one curve (relation) only being drawn for each sample. Past experience with a seasonal breakdown in similar watersheds has not been satisfactory. Seasonal differences in P versus Y relations do apparently occur, but they are neither large enough nor consistent enough to be useful.

Average "Peak Stage versus Precipitation" curves were developed for later use in determining flood damages. The peak stage for each significant storm was plotted against the precipitation causing the stream rise and an average curve drawn. From this average Peak Stage versus Precipitation curve and the P versus Y curve, a "Peak Stage versus Y" curve can be determined whenever it is needed. This was done in preliminary studies, but it was not used in the final study of the evaluation series. The average Peak Stage versus Precipitation curve for conditions after channel improvement has been made was determined from the above curves and from the channel improvement studies.

The P versus Y curves for the two sample tributaries are shown in Figures C-2 and C-3. The Peak Stage versus Precipitation curves are shown in Figures C-4 and C-5.

The Evaluation Series of Floods

1. Barren River. The actual series of floods recorded at the gage on Barren River near Pageville, Kentucky, for the 10-year available record (October 1, 1939, to September 30, 1949, for complete water years) was used as the evaluation series of flood events. During this period 54 definite rises occurred, most of which were analyzed

for use in the P versus Y relation. However, not all of these caused appreciable out-of-bank flow and hence flood damage. "Bankfull stage" occurs at about 14.0 feet (gage reading), which corresponds approximately to the average rise caused by a rainfall of 1.75 inches, Table C-2 lists the 35 rises causing appreciable inundation during this 10-year period, and tabulates precipitation, present and future flood runoff and present and future gage heights.

2. <u>Pond River</u>. The stream gage near White Plains, Kentucky, was in operation only three years (October 1937 to September 30, 1940). Consequently, the record was supplemented by the gage near Apex, Kentucky, higher up on the same stream. This Apex gage is considerably above the White Plains gage, having a drainage area of 196 square miles as compared to 324 square miles above White Plains. However, the Precipitation versus Runoff relation obtained from the stream rises at the Apex gage was similar enough to that at the White Plains gage to indicate a reasonably close relation between the two records. The final Precipitation versus Runoff average relation was adopted after consideration of the records at both gages, the Apex record being modified as necessary to bring it into conformity to the rises that the corresponding precipitation would have caused at the White Plains gage.

Nine storms were analyzed for the three-year record at White Plains and 39 were analyzed at the Apex gage. In addition the record was carried back another year (to October 1, 1936) by an analysis of the rainfall on the area above White Plains and the study of stream-flow records of nearby stream gages. In all, 58 storms were analyzed, completely or partially, covering a total period of thirteen years, from October 1, 1936, to September 30, 1949. These 58 rises were used as the evaluation series of floods for the Pond River sample tributary.

"Bankfull stage" occurs at about 11.5 feet (gage reading at the White Plains gage); this corresponds approximately to the average rise caused by a rainfall of 1.65 inches. Table C-3 (2 sheets) lists the 53 storms causing appreciable inundation during this 13-year period, and tabulates precipitation, runoff, and gage heights.

<u>Development of Infiltration Data</u>

<u>The Infiltration Formula</u> - Infiltration data from the entire United States have been collected and analyzed by the Soil Conservation Service Washington office. The result has been condensed into an empirical formula (in two parts) which simplifies the application of the data to actual cases. The formula is:

$$\theta = C \left[.178 \div (S \div k) \right] - .178, \text{ when } S + k > .20,$$

$$\theta = C \left\{ .604 \div (S \div k) \right\} - .604, \text{ when } S + k < .20.$$

The symbols have the following meanings.

The coefficient S was introduced into the formula to measure the effect of soil on the infiltration rate, using soil texture as the criterion. (See "Soil Classification.")

The coefficient C measures the effect of cover conditions on the run-off. (See "Cover Conditions: Evaluation Classes.")

The watershed coefficient (correction factor) k and the infiltration rate (index) θ are explained under the heading: "Computation of the Index θ."

Detailed explanations and computations are not given here since these are available in Regional and Washington files of the Soil Conservation Service. However, in the sections immediately following, methodology especially applicable to this survey is briefly described.

Analysis of Intensity of Precipitation Records - Use of the infiltration theory (either by an empirical formula or by direct analysis) requires the preparation of an average "dimensionless diagram" for one or more stations which can be considered representative of the area under consideration. Preparation of such a dimensionless diagram requires intensity-of-precipitation records for 5-minute intervals, for a fairly long period of record (about ten years for really representative results). As remarked in a previous section ("Precipitation and Stream-flow Data"), no stations with such records were available within the Green River Watershed, and only Louisville and Lexington were available in Kentucky. Since these two stations are considerably north of the Green River and have a much lower average annual rainfall, they are not representative. Other possible stations in the general area are Chattanooga, Knoxville, Memphis, and Nashville, all in Tennessee. These were investigated for average rainfall and runoff as compared with such averages in the Green River Watershed (in particular, in the middle and upper reaches of this watershed, where the rainfall causing most of the floods originates).

Average annual rainfall in the combined middle and upper portions of the Green River Watershed is about 49.5 inches (as compared with about 46.5 for the entire watershed) with a range from about 46.0 to about 51.5 inches. Average annual runoff is about 18 inches per year over the sample tributary areas, going up to about 20 inches in the headwater areas. (See "Annual Runoff in the United States," U. S. Geological Survey Circular 52, 1949.)

Of the six stations mentioned above, Chattanooga, Tennessee, has already been analyzed and its average dimensionless diagram determined. As the Chattanooga dimensionless diagram was found to be practically the same as that for Atlanta, Georgia, the two were combined. This dimensionless diagram thus represents the combined Chattanooga, Tennessee, and Atlanta, Georgia, area, which has an average annual rainfall of about 50 inches, with a range from 48.0 to 51.5 inches. The average annual runoff of the combined area is about 19 inches, with a range from 17 to 21 inches. The Chattanooga-Atlanta area is thus reasonably representative, as to rainfall and runoff, of the middle and upper Green River Watershed areas.

The corresponding average annual rainfall and runoff figures for the other available stations are:

Lexington, Kentucky: 43.4 inches and 17.5 inches,
Louisville, Kentucky: 43.3 inches and 16 inches,
Knoxville, Tennessee: 47.4 inches and 19 inches,
Memphis, Tennessee: 49.7 inches and 17 inches,
Nashville, Tennessee: 47.2 inches and 19 inches.

The only one of these (Memphis) which agrees as to rainfall has too low an average annual runoff, so that the Chattanooga-Atlanta record seems on the whole the best available for the Green River sample tributary areas (including the larger part of the areas to which the sample tributary data will be expanded).

The dimensionless diagram is based on an analysis of intensity of rainfall; hence the mere agreement of two localities as to rainfall and runoff is not sufficient by itself to prove that they will have similar dimensionless diagrams. However, such an agreement (especially as to relative runoff, which is a reflection of "storm patterns" as well as of topography) is important and indicates a probable similarity in the average intensity patterns of the storms in the two areas, particularly if these areas are approximately similar in topography.

A more direct indication of the agreement, as to storm intensity patterns, between the Green River sample tributary areas and the Chattanooga-Atlanta combined area comes from the Precipitation versus Runoff investigation made for these sample tributaries. The storm rainfall for the two sample tributaries, as actually determined for about 100 storms, shows a rather noticeable low proportion of the high-intensity rains. This corresponds with the Chattanooga-Atlanta dimensionless diagram, which indicates by its shape a lower proportion of such storms than is shown by most of the other dimensionless diagrams so far computed.

Dimensionless diagrams have been computed for several stations in Missouri (Springfield, Hannibal, and St. Louis) which, geographically, are within reasonable distances of the Green River Watershed. A very brief investigation showed, however, that they are unsuitable. They represent areas with an average annual runoff of from 12 inches down to 8 inches, far below that of the Green River Watershed. The three dimensionless diagrams, also (particularly those for Hannibal and St. Louis) indicate a much higher proportion of high-intensity storms than occurs on the Green River areas.

The above considerations led to the selection of the Chattanooga-Atlanta dimensionless diagram for use in this survey. It is shown in Figure C-6.

In addition to the dimensionless diagram, the analysis of the storms at Chattanooga and Atlanta gave the values:

$I_{max} = 1.60$ inches per hour for $P = 1.50$ inches,

$I_{max} = 2.20$ inches per hour for $P = 3.50$ inches,

$I_{max} = 3.00$ inches per hour for $P = 6.00$ inches,

with proportional values for other precipitations.

From the dimensionless diagram and the I_{max} values, the "P_0 curves" or "Rainfall Excess Graphs" for each of three selected storms were computed. (See Figure C-7.) Their construction and use is explained in discussions on file in the Soil Conservation Service Regional and Washington offices.

Soil Classification - A classification with respect to texture was made of the soils in the watershed. Texture, as used here, is defined as the relative proportion of the three size groups (clay, silt, and sand) of individual grains in the soil. These were found originally by mechanical analysis or by field determination. The classification was made solely for use in the infiltration formula and thus occasionally grouped together soils which are not similar in other respects. The table below shows the classification used in the Green River survey.

Soil Classification as to Texture (for use in the Infiltration Formula)

Physical Land Unit and Soils	Area in Sample Tributary (sq. mi.)	Texture % of Clay	Texture % of Silt	Texture % of Sand
Pennyroyal:				
Silt loam	441.0	10	65	25
Silty clay loam	69.3	25	65	10
Silty clay to clay	14.6	40	50	10
Loam to sandy loam	10.1	10	40	50
Western Coal Field:				
Silt loam	167.4	10	65	25
Silty clay loam	87.7	25	65	10
Silty clay to clay	3.9	40	50	10
Loam to sandy loam	65.0	10	40	50

A value of the coefficient S of the infiltration formula corresponds to each set of the three percentages which define the texture of a given soil. This value S is found by using a triangular chart, not reproduced here, but available in the files of the Soil Conservation Service Regional and Washington offices. For the four textures shown in the above table, the S values are 0.370, 0.140, 0.004, and 0.527, respectively.

Cover Conditions, Evaluation Classes - A cover classification for hydrologic use is required for the infiltration formula, since the formula contains a cover coefficient ("factor of cover") C, which has various values depending on the cover. The cover classification need not be a very detailed one for our present purposes; hence it groups together some of the individual classes contained in the classification used in planning the land treatment measures.

The values of the "cover coefficient" C as used in the infiltration formula, for the cover conditions occurring in the watershed, are as follows:

Values of Cover Coefficient C

Cover Description	C	
	$S+k < .20$	$S+k > .20$
Row Crops* and Miscellaneous	1.00	1.00
Poor Pasture and Poor Abandoned	1.02	1.042
Poor Woods	1.04	1.094
Small Grain and Good Abandoned	1.09	1.185
Medium Past., Close Growing, Poor Kudzu	1.17	1.360
Good Pasture and Medium Woods	1.25	1.541
Good Woods and Good Kudzu	1.36	1.770

*Row Crops are in this first (poorest) class for present conditions. For future conditions, Row Crops are classed with Poor Pasture, etc., as the improved practices recommended in the land treatment measures should also increase the infiltration rates for land in row crops.

Each of the seven cover types just listed, for each soil classification, gives an evaluation class corresponding to the "soil-cover complex" used formerly in the analysis of infiltration data.

Areas of Evaluation Classes in Each Sample Tributary - These areas were determined in each of the physical land units and in each sample tributary. The areas were taken from the tables used in planning land treatment measures and regrouped according to the hydrologic "evaluation classes." Detailed tables showing the computation and grouping used are on file in the Soil Conservation Service Regional office.

The stream discharges (which are known for the period of record) are the discharges coming from the present distribution of cover conditions, assuming that no radical changes in cropping practices, etc., have taken place during this period of record. Hence, in order to make measured flood discharges and present evaluation class areas comparable, these areas for the sample tributaries were taken as the actual present areas within the sample watershed. Field investigations verified that no extensive changes in general land use practices have occurred within the period of record.

For future conditions, the determination of the areas recommended for the various land use measures was made directly on a physical land use basis. Hence these computed areas were used for the future conditions and scaled down by proportion to give the corresponding sample tributary areas. If a sample tributary represented its physical land unit exactly in all respects, the present and future areas in the sample tributaries, as found by this procedure, would be exactly comparable. In practice there is some lack of agreement, but as the sample tributaries are reasonably representative, no serious error results from this cause.

Computation of the Index θ - A value of C and of S was determined for each evaluation class, as previously explained. A series of trial computations was next made, using the infiltration formula, to determine the "watershed correction factor" k and the corresponding values of θ in each case. Trial computations were continued until the values of θ thus found would give a storm runoff equal to that actually obtained in the Precipitation versus Runoff investigation previously described.

Computation of Storm Runoff, Present and Future - It was assumed that in the future approximately the same hydrologic conditions will hold as at present, the only difference being the areas of each evaluation class. Thus the same k and θ values were used for both present and future computations and for all design storms. The results for the present of course agree closely with the P versus Y relation previously obtained, since the watershed correction factor k was selected to satisfy this relation.

The detailed computations for P_c, present and future, are on file in the Soil Conservation Service Regional office. Sample computations are available in the files of the Soil Conservation Service Washington office. See Figure C-2 for the results of the storm runoff computation for the Barren River sample tributary, and Figure C-3 for Pond River.

The use of the infiltration formula automatically makes the present computed P versus P_c (P versus Y) relation the same as the present observed P versus Y relation. This would still be true, in general, if the runoff Y included a large amount of "quick return flow" or "subsurface runoff" coming from areas with shallow profile soils. The infiltration method (whether by use of a formula or by direct analysis) is intended to be applied directly only to cases where most of the storm runoff is the usual "surface runoff" consisting of water which has not infiltrated into the ground at all, as contrasted to the "subsurface storm runoff" from thin soils. Hence it is necessary to investigate the possibility of the occurrence of subsurface flow in large enough amounts to complicate the application of the infiltration theory.

There are areas of thin profile soils in each of the sample tributaries, and some subsurface flow is undoubtedly present in the storm runoff. However, it is not believed the proportion of subsurface flow is large enough to cause errors in the computation of future storm runoff by direct application of the infiltration theory without correction for subsurface flow. This conclusion seems confirmed by the list of observed average storm runoffs Y for a 4-inch rainfall, as taken from other surveys. Since the P versus Y curves are of approximately similar shape, one value, using a moderately heavy rainfall, is sufficient to determine the general relation between watersheds.

Storm Runoff (Y) Values for a 4-inch Rain

Tributary	Physical Land Unit	Y(inches) for P = 4.00 in.
Green River		
Barren River	Pennyroyal	1.30
Pond River	Western Coal Field	1.60
Savannah River		
Keowee River	Mountain-Foothills	1.33
Broad River	Piedmont Plateau	1.27
Little River (S.C.)	Piedmont Plateau	1.72
Pee Dee River		
Fisher River	Mountain-Foothills	2.15
Third Creek	Piedmont Plateau	1.25
Roanoke River		
Upper Roanoke River	Limestone Valley	1.65
Blackwater River	Mountain-Foothills	1.33
Sandy River	Piedmont Plateau	1.60
Falling River	Piedmont Plateau	1.25

Fisher River is known to have considerable subsurface flow. The other streams in the Savannah, Pee Dee, and Roanoke River Watersheds are known to have no significant return flow. The two Green River sample tributaries show a present average storm runoff well within the range of those streams having no significant subsurface flow. (The values listed for the Green River tributaries must be raised somewhat to make them comparable with the others, because antecedent rain was considered in the Green River only, but the amount of this correction is not enough to raise the Green River Y values above this range.) Thus the table confirms the correctness of omitting special consideration of subsurface flow for these Green River tributaries.

"Subsurface runoff" as used above does not have reference to the type of subsurface drainage by channels that exists in the Karst areas. This subsurface channel drainage may, in some cases, cause considerable uncertainty in the relation between rainfall and the runoff in a particular area, but without a detailed subsurface survey there is no way to consider it from a hydrologic standpoint.

Future Storm Runoff from Wooded Areas - Future acreage of medium woods and good woods may be derived from various present covers. It has been decided to claim as benefits from future medium woods and future good woods only those benefits coming from a 15-year growth, on the average, except it is assumed that existing good woods will remain good woods of the best hydrologic type. Thus future good woods derived from existing poor woods or existing medium woods or from open land of any sort will not be claimed as good woods of the best hydrologic type. Data exist which indicate that in general it takes more than 15 years for such woods to reach the best hydrologic conditions. Thus it is necessary to separate future medium woods and future good woods acreage into two classes each before using these acreages to obtain future estimated runoff.

Data also exist which indicate that for average plantings the condition of "good" woods 15 years after establishment corresponds approximately, from the hydrologic standpoint, to an infiltration coefficient which represents 80 percent of the spread between medium woods and good woods conditions (instead of 100 percent spread as for the best type of good woods). Similar results follow from the data for new "medium" woods, 15 years after establishment, with respect to poor woods.

Detailed discussion of this modified classification of medium and good woods and the computation of the corresponding θ values, are on file in the Soil Conservation Service Regional office.

Channel Improvement

Reconnaissance showed that simple channel improvement work such as snagging, and tree removal from the channel itself, would in general be beneficial in the watershed. An investigation was therefore made to determine the effect of such measures from the hydrologic standpoint.

Standard methods were used in this investigation. Approximate gage height versus discharge curves (rating curves) for present conditions and for future conditions (after channel improvement) were determined at one or more typical cross-sections of the stream. The reduction in gage height for a given discharge, due to the channel improvement, was then found from these curves.

The values of the water-surface slope "S" at selected cross-sections, the cross-sections and notes about conditions affecting the present value of "n" (the coefficient of roughness in Manning's formula) were determined by field work. "Slope-area" computations by Manning's formula, using this present value of n, gave the present rating curve. As a check on the estimated value of present n, a preliminary computation was made in each case for the cross-section at the stream gage. Here an accurate rating curve was available from U. S. Geological Survey records; with this rating curve and the measured water-surface slope and cross-section, the values of n can be determined which will reproduce the rating curve. When the cross-section at the gage seemed to be representative of the general valley conditions of the stream, this cross-section was given major weight in the investigation because its

present rating curve was known. When the gage cross-section was not representative for any reason, one or more other cross-sections were also investigated and the results considered in determining the final rating curve for present and future.

For conditions after channel improvement the same slope s and the same cross-section values were used as for present conditions. New values of n were used for the future channel section, however. These values of n were estimated from an estimate of future conditions, and from various investigations which have been made on the values of n for "before and after" conditions on streams similar to the ones under consideration. The value of n for the overflow section (flood plain) was kept the same for the future as for the present since no improvement in the flood plain is contemplated by the channel improvement measures.

Present and future rating curves for the Barren River sample tributary are shown in Figure C-8. Present values of n for the channel section were high, averaging about 0.065. Future values were estimated to average about 0.057. On this sample, the gage section was reasonably representative.

Rating curves for the Pond River sample tributary are shown in Figure C-9. Present values of n for the channel section averaged about 0.055. Future values were estimated to average about 0.046. As the rating curves in Figure C-9 indicate, the total effect of channel improvement was less at comparable gage heights than for Barren River. This was largely due to very wide flood plains on the Pond River, which caused a loss of effectiveness due to improvement in the channel only. See also Figures C-14 and C-15, which show the percentage reduction in gage heights due to channel improvement. The gage section (at the White Plains gage) had too wide a flood plain to be representative for the stream as a whole, even taking account of the wide flood plains occurring over much of the river. This section was supplemented by a study of several other sections, and the results adjusted to correspond to the general conditions.

The "Peak Stage versus Precipitation" curves of Figure C-4 (Barren River) and Figure C-5 (Pond River) each include a curve for conditions after channel improvement. This "after channel improvement" curve combines the results shown by the present peak stage curve of Figure C-4 (or C-5) and the future (after channel improvement) rating curve of Figure C-8 (or C-9), but is in a convenient form for use.

Effect of the Recommended Program on Flood Reductions

The present and future P versus P_e (P versus Y) relations, found for each sample tributary, were used to determine the hydrologic effect of the recommended land use measures. These P versus P_e relations were assumed to apply in general to the physical land unit represented by the sample. Thus, Figure C-2 gives the curves (relations) used for both the Barren River sample tributary and for all the tributaries in the Pennyroyal Physical Land Unit.

The future Y and Peak Stage values of Table C-2(and C-3) were found from the present values and the curves of Figure C-2 (and C-3) and Figure C-4 (and C-5).

The percentage reductions in the runoff Y due to the recommended program are shown in Figures C-12 and C-13.

The percentage reductions in gage heights due to channel improvement alone and to channel improvement combined with the recommended program are shown in Figure C-14 (for the Barren River) and in Figure C-15 (for the Pond River).

Stage versus Area Inundated

The area inundated for various flood stages (gage heights on the gage for the sample tributary) was determined for each sample tributary and the physical land unit it represents as outlined below.

1. A profile of mean low water elevation, referenced to the gage on the stream, was obtained by the Engineering Section from a field survey. Representative valley and channel cross-sections were obtained at the same time, located to give a reasonable coverage showing the average conditions. This profile and the series of cross-sections covered the length of the sample tributary from the gage to a point above which inundation was not significant. The profile and cross-sections were plotted to scale.

2. High water marks of historic floods at various points were determined by field investigation and referenced to the profile (and to the zero of the gage). Field work was concentrated on two selected floods of fairly recent date having flood crests different enough to give two maximum flood crest lines reasonably far apart on the flood plain.

3. The high water marks were plotted on the aerial photographs and their elevations indicated. Profile elevations were located on the photographs, and also the cross-sections to scale, with elevations indicated. Any other points whose locations and elevations were known were also plotted on the photographs.

4. With the aid of these points plotted on the aerial photographs, the line of maximum inundation (boundary of the area of inundation) was drawn on the photographs by stereoscopic methods for each of the two selected floods. This line of maximum inundation (maximum crest line) of a flood is not a contour line, but in general it is sufficiently near level so that a stereoscope can be used.

5. The area inundated by each of the two selected floods was then planimetered directly from the aerial photographs. Reaches of the stream were used, for convenience, based on the surveyed cross-sections and on intermediate cross-section lines located approximately on the photographs.

6. Areas inundated by floods intermediate between the two selected floods, and by floods greater or less than these two were found (by reaches) by an approximate formula. This formula assumes that for a given stage the ratio of the area inundated at that stage, to the planimetered maximum area inundated for a given reach, is proportional to the ratio of the sum of the widths of inundation for the

given stage to the sum of the widths of inundation for the maximum flood, the end sections of the reach being used for these widths. For assumed gage heights below or nearer the lower of the two selected floods, data from this lower flood were used instead of from the maximum flood. Since this area of inundation formula is approximate, results from it were examined for reasonableness and checks made if necessary, even to the extent of considering "concordant flow" at a cross-section when simpler methods did not decide the question.

7. The total area thus found was corrected to give open land only (See Appendix D) and was expressed as average "area inundated per mile of stream." The results were put in tabular form and, in combination with present and future gage heights (as listed in Tables C-2 and C-3) and flood damage estimates on an areal basis, were used to compute damage and benefit figures. The data from the area inundated tables are plotted in Figures C-10 and C-11.

Stage versus Duration of Inundation

Since in many cases the damage caused by flood inundation is clearly dependent upon the duration of time the fields are under water, it was necessary to consider duration of inundation. A study of the duration of inundation computed for each storm on the tributaries of the Coosa River above Rome, Georgia, showed that there was no significant relationship, from the standpoint of damage, between flood heights (only) and duration of inundation. Different floods of course result in different durations of inundation, but gage height or depth of flooding alone does not determine the average duration. Hence the survey party handled this phase of the damage problem by methods not depending on a hydrologic investigation.

For many storms the duration of inundation for the various depths of inundation was about one-quarter day for depths of 1 and 2 feet, and one-half day for depths of 3 and 4 feet.

MAIN STREAMS

Investigation by members of the survey party on the probable damage reductions to be expected on the main streams, from the measures recommended in the report, indicated that detailed methods (tying in the damages and the benefits to actual flood heights on the main streams) were not advisable. Probable total damage reductions on the main streams were not great enough to warrant such details in this survey.

Field investigation indicated that the part of the Green River in the Pennyroyal Physical Land Unit (approximately 160 miles of stream) could be best considered as a "tributary." It was therefore included in the stream miles to which the Barren River sample was expanded. This part of the Green River had flood plains of considerable width, and in general the entire upper reaches of the Green River were well represented by the Barren River sample tributary.

From the mouth up to the boundary of the Pennyroyal Physical Land Unit (about 220 miles) the indicated reductions in flood damages along the main stream, due to the recommended program, were so small that a detailed analysis was not necessary.

See Appendix D for a more detailed discussion.

Table C-1
HORTON-THIESSEN WEIGHTS FOR THE SAMPLE TRIBUTARIES
(Percent of Tributary Watershed Area Within
the Precipitation Polygon)
GREEN RIVER, KENTUCKY, WATERSHED

Tributary	Period During Which the Given Weights Were Used	Precipitation Stations												
		Adolphus	Bowling Green	Celina *	Glasgow	Lucas	Red Boiling Springs *	Scottsville	Tompkinsville	Dunmor	Earlington	Greenville	Haleys Mill	Hopkinsville
Barren River	Feb.-May, 1940; 1942, 1943, 1944	-	-	50	50	-	-	-	-	-	-	-	-	-
	Jan., Feb., 1941	50	-	40	10	-	-	-	-	-	-	-	-	-
	July, 1941	25	-	-	-	15	-	-	60	-	-	-	-	-
	Jan., March, April, 1945	-	-	4	8	-	88	-	-	-	-	-	-	-
	May-Dec., 1945 Jan., April, 1946	-	-	5	-	-	95	-	-	-	-	-	-	-
	Feb.-Dec., 1946 Feb., 1947	-	-	5	-	-	65	30	-	-	-	-	-	-
	Jan., May, 1947 1948 (most)	-	-	-	-	-	40	30	30	-	-	-	-	-
	June-Aug., 1947 Feb., 1948	-	-	-	-	-	65	-	35	-	-	-	-	-
Pond River	1936-1939; Parts of 1940, 1948	-	-	-	-	-	-	-	-	-	5	60	-	35
	Dec. 1940 - 1949, inclusive	-	-	-	-	-	-	-	-	5	-	20	70	5
	1942, 1944 (Occasional)	-	-	-	-	-	-	-	-	-	-	60	-	40

* In Tennessee; all other stations are in Kentucky.

Table C-2 (Sheet 1 of 1)
EVALUATION SERIES OF FLOODS
WHICH CAUSED APPRECIABLE INUNDATION
Barren River Sample Tributary
GREEN RIVER, KENTUCKY, WATERSHED

Storm Data		Present		Future			
					After Channel Improvement and after Land Program		
Date	1/ Rainfall P (in.)	Avg. Runoff Y (in.)	Avg. Peak Stage (ft.)	Peak Stage After Channel Impr. (ft.)	Average Y (in.)	Avg. Peak Stage (ft.)	Percent Reduction in Stage
2/19/40	1.96	0.48	14.95	14.0	0.28	11.2	25.1
3/31/40	2.78	.77	17.0	16.2	.52	14.4	15.3
4/20/40	3.20	.93	17.8	17.0	.67	15.5	12.9
7/5/41	3.85	1.20	18.95	18.2	.92	17.05	10.0
1/2/42	2.05	.51	15.2	14.2	.30	11.65	23.4
4/10/42	2.44	.65	16.2	15.3	.42	13.2	18.5
7/9/42	2.24	.58	15.7	14.8	.35	12.4	21.0
11/23/42	3.01	.87	17.45	16.6	.61	15.0	14.0
12/29/42	4.45	1.48	19.8	19.1	1.18	18.1	8.6
3/14/43	3.09	.90	17.6	16.8	.64	15.2	13.6
3/20/43	3.40	1.01	18.05	17.3	.74	15.85	12.2
4/24/43	2.35	.61	16.0	15.0	.38	12.9	19.4
2/18/44	2.85	.80	17.1	16.2	.55	14.55	14.9
2/29/44	3.38	1.00	18.0	17.2	.73	15.8	12.2
3/20/44	2.78	.77	17.0	16.2	.52	14.4	15.3
9/1/44	5.25	1.88	21.0	20.4	1.56	19.5	7.1
1/1/45	4.66	1.58	20.1	19.4	1.28	18.45	8.2
2/18/45	2.16	.56	15.5	14.6	.33	12.1	21.9
2/22/45	4.04	1.30	19.25	18.5	1.02	17.45	9.4
2/28/45	4.65	1.58	20.1	19.4	1.28	18.45	8.2
1/18/46	8.50*	3.81	24.45	24.0	3.49	23.6	3.5
2/7/46	3.20	.93	17.8	17.0	.67	15.5	12.9
3/8/46	2.25	.59	15.75	14.8	.36	12.45	21.0
1/3/47	3.23	.94	17.9	17.1	.68	15.6	12.8
1/16/47	3.65	1.11	18.55	17.8	.84	16.5	11.0
5/22/47	5.74	2.13	21.6	21.0	1.81	20.15	6.7
7/16/47	2.68	.73	16.8	15.9	.49	14.1	16.1
1/2/48	2.31	.60	15.95	15.0	.37	12.75	20.1
2/14/48	4.75	1.61	20.25	19.6	1.31	18.6	8.1
3/27/48	2.37	.62	16.05	15.1	.39	12.95	19.3
11/5/48	3.14	.92	17.65	16.8	.66	15.35	13.0
12/15/48	2.58	.70	16.55	15.6	.46	13.75	16.9
3/18/49	2.60	.70	16.6	15.7	.46	13.8	16.9
6/16/49	6.00*	2.24	21.9	21.4	1.92	20.65	5.7
6/27/49	2.44	.65	16.2	15.3	.42	13.2	18.5

1/ Adjusted for antecedent rain when necessary.
* Adjusted for areal and time distribution of rain.

Table C-3 (Sheet 1 of 2)
EVALUATION SERIES OF FLOODS
WHICH CAUSED APPRECIABLE INUNDATION
Pond River Sample Tributary
GREEN RIVER, KENTUCKY, WATERSHED

Storm Data		Present		Future			
					After Channel Improvement and after Land Program		
Date	1/ Rain-fall P (in.)	Avg. Runoff Y (in.)	Avg. Peak Stage (ft.)	Peak Stage After Channel Impr. (ft.)	Average Y (in.)	Avg. Peak Stage (ft.)	Percent Reduction in Stage
11/4/36	3.54	1.33	16.2	15.8	1.02	14.6	9.9
12/6/36	1.94	.595	12.8	11.8	.415	9.6	25.0
1/22/37	11.55	6.44	23.2	23.1	6.15	22.75	1.9
5/3/37	4.44	1.83	17.35	17.0	1.47	16.15	6.9
6/10/37	1.79	.52	12.15	11.0	.36	8.65	28.8
7/4/37	2.04	.64	13.2	12.2	.45	10.3	22.0
8/9/37	1.78	.515	12.1	10.9	.355	8.55	29.3
9/11/37	1.91	.59	12.65	11.6	.41	9.4	25.7
3/17/38	3.33	1.23	15.95	15.5	.94	14.3	10.4
8/4/38	5.85	2.61	18.9	18.7	2.21	17.95	5.0
2/5/39	5.35	2.33	18.35	18.2	1.94	17.3	5.7
3/7/39	2.96	1.05	15.3	14.8	.78	13.4	12.4
4/2/39	2.58	.88	14.6	14.0	.64	12.35	15.4
4/18/39	2.88	1.00	15.2	14.6	.74	13.25	12.8
3/5/40	2.49	.83	14.4	13.8	.60	12.05	16.3
3/15/40	2.71	.93	14.85	14.2	.68	12.75	14.1
4/19/40	5.40	2.38	18.4	18.2	1.99	17.35	5.7
6/3/41	2.90	1.01	15.2	14.6	.75	13.25	12.8
6/8/41	3.58	1.35	16.25	15.8	1.04	14.7	9.5
2/16/42	1.89	.59	12.5	11.4	.41	9.15	26.8
3/16/42	2.30	.75	14.0	13.2	.54	11.45	18.2
4/9/42	5.60	2.48	18.6	18.4	2.09	17.65	5.1
3/11/43	2.77	.97	15.0	14.4	.72	12.95	13.7
3/18/43	2.73	.94	14.9	14.3	.69	12.8	14.1
2/25/44	2.82	1.00	15.1	14.6	.74	13.1	13.2
4/10/44	2.55	.86	14.5	13.8	.63	12.2	15.9
5/4/44	2.91	1.02	15.25	14.7	.76	13.35	12.5
12/31/44	2.57	.87	14.6	14.0	.64	12.35	15.4
1/7/45	2.40	.79	14.2	13.4	.57	11.75	17.3
2/21/45	1.72	.50	11.85	10.6	.34	8.15	31.2

1/ Adjusted for antecedent rain when necessary.

Table C-3 (Sheet 2 of 2)
EVALUATION SERIES OF FLOODS
WHICH CAUSED APPRECIABLE INUNDATION
Pond River Sample Tributary
GREEN RIVER, KENTUCKY, WATERSHED

Storm Data		Present		Future			
					After Channel Improvement and after Land Program		
Date	1/ Rain-fall P (in.)	Avg. Runoff Y (in.)	Avg. Peak Stage (ft.)	Peak Stage After Channel Impr. (ft.)	Average Y (in.)	Avg. Peak Stage (ft.)	Percent Reduction in Stage
2/26/45	2.44	0.80	14.3	13.6	0.58	11.9	16.8
3/5/45	2.13	.68	13.4	12.5	.48	10.55	21.3
3/17/45	3.23	1.19	15.8	15.4	.90	14.1	10.8
1/8/46	4.23	1.72	17.1	16.8	1.36	15.8	7.6
2/5/46	3.27	1.20	15.85	15.4	.91	14.15	10.7
2/13/46	2.90	1.01	15.2	14.6	.75	13.25	12.8
3/26/46	2.35	.77	14.05	13.3	.56	11.55	17.8
1/2/47	3.11	1.11	15.6	15.2	.83	13.8	11.5
4/8/47	2.48	.82	14.4	13.8	.60	12.05	16.3
4/15/47	2.25	.72	13.8	13.0	.52	11.15	19.2
5/19/47	3.41	1.27	16.0	15.6	.97	14.35	10.3
5/25/47	2.91	1.02	15.25	14.7	.76	13.35	12.5
2/13/48	1.87	.58	12.4	11.3	.40	9.0	27.4
3/16/48	1.74	.51	12.0	10.8	.35	8.4	30.0
3/27/48	2.78	.98	15.0	14.4	.72	12.95	13.7
4/12/48	2.39	.79	14.15	13.4	.57	11.7	17.3
12/15/48	3.85	1.51	16.6	16.2	1.18	15.15	8.7
1/18/49	1.97	.60	12.9	11.9	.42	9.75	24.4
1/24/49	4.16	1.67	17.0	16.7	1.32	15.65	7.9
2/14/49	5.63	2.49	18.65	18.4	2.10	17.7	5.1
3/26/49	2.35	.77	14.05	13.3	.56	11.55	17.8
6/15/49	3.43	1.29	16.05	15.6	.99	14.4	10.3
6/27/49	1.93	.60	12.7	11.6	.42	9.45	25.6

1/ Adjusted for antecedent rain when necessary.

KENTUCKY
Green River Watershed
TENNESSEE
LOCATION MAP
OHIO R.
WESTERN
WESTERN
COAL
FIELD
HENDERSON
DAVIESS
WEBSTER
McLEAN
HOPKINS
MUHLENBERG
CHRISTIAN
TODD
LOR
CASEY
LINCOLN
AIR
PULASKI
RUSSELL
Panther Cr.
South
Green
Deer Cr.
Otter Cr.
Pond
Elk Cr.
River
Cr.
RIVER
Trace Fk.
Sulphur
Cr.
Earlington
WHITE PLAINS (NEAR)
Greenville
APEX (NEAR)
Long
Clifty Cr.
Pond
Dunmor
Haleys Mill
West Fk.
Fk.
Enterprise
Hopkinsville
LEGEND
STREAM GAGING STATION (USED IN THE INVESTIGATION)
RAINFALL STATION (ONLY STATIONS ACTUALLY USED IN THE INVESTIGATION ARE SHOWN)
SAMPLE TRIBUTARY WATERSHED BOUNDA
PHYSICAL LAND UNIT BOUNDARY
FIG. C-1
PARTMENT OF AGRICULTURE
CONSERVATION SERVICE
H. H. BENNETT, CHIEF
OUTHEASTERN REGION
. BUIE, REGIONAL DIRECTOR
RIVER WATERSHED
IN
CKY AND TENNESSEE
SHOWING
ICAL LAND UNITS
0
10
20 MILES
4-20-50

2-N-6145D-2

FIG. C-1

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
H. H. BENNETT, CHIEF
SOUTHEASTERN REGION
T. S. BUIE, REGIONAL DIRECTOR

GREEN RIVER WATERSHED
IN
KENTUCKY AND TENNESSEE
SHOWING
PHYSICAL LAND UNITS

2-N-61450-2

April 1950

Figure C-2
PRECIPITATION VERSUS RUNOFF RELATIONS
(PRESENT AND FUTURE)
for
Barren River Sample Tributary
(Pennyroyal Physical Land Unit)
GREEN RIVER, KENTUCKY, WATERSHED

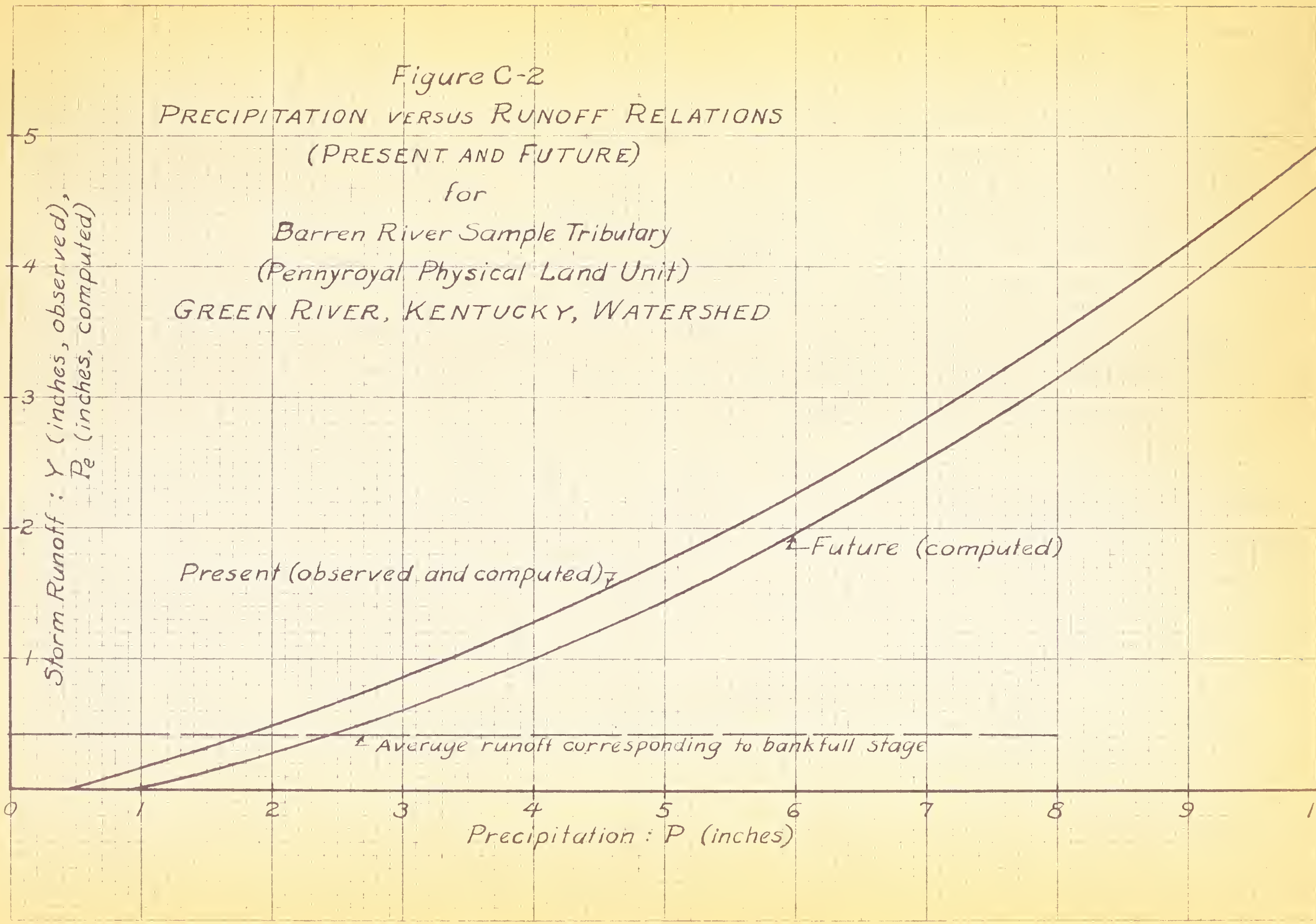


Fig. C-2

April 1950

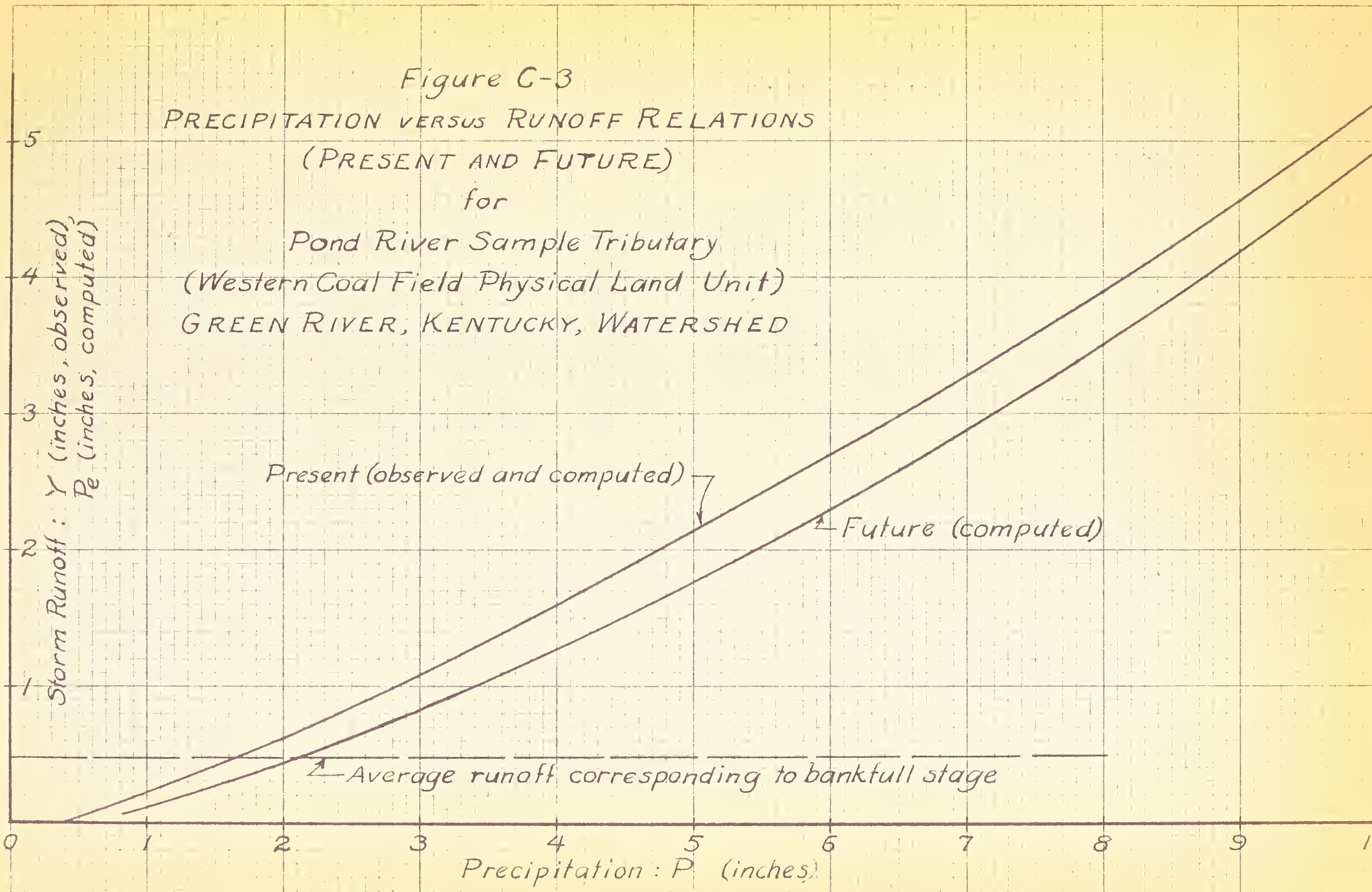


Figure C-3
PRECIPITATION VERSUS RUNOFF RELATIONS
(PRESENT AND FUTURE)
for
Pond River Sample Tributary
(Western Coal Field Physical Land Unit)
GREEN RIVER, KENTUCKY, WATERSHED

Fig. C-3

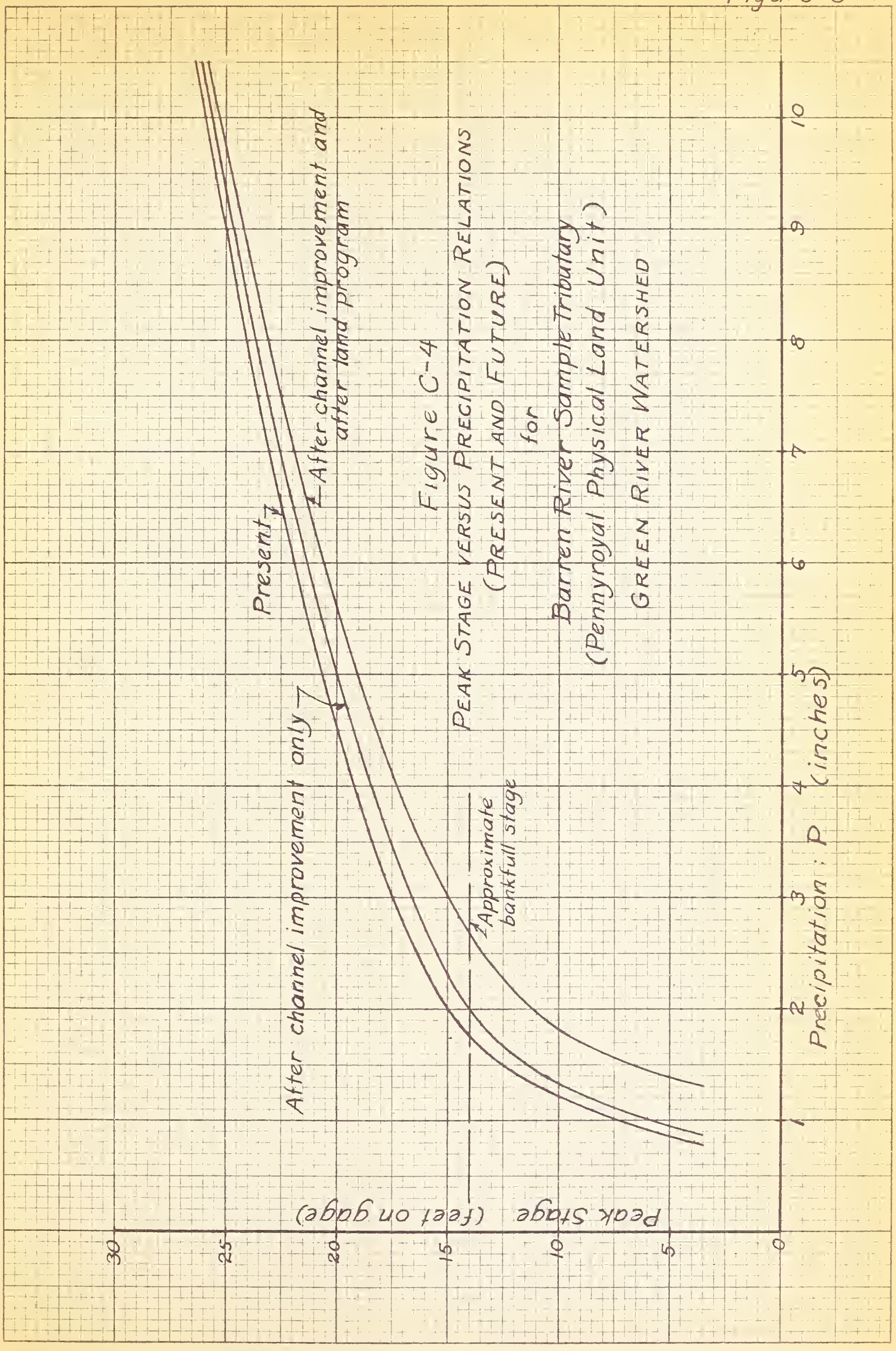


Figure C-4
PEAK STAGE VERSUS PRECIPITATION RELATIONS
(PRESENT AND FUTURE)
for
Barren River Sample Tributary
(Pennyroyal Physical Land Unit)
GREEN RIVER WATERSHED
Present
After channel improvement and after land program
After channel improvement only
Approximate bankfull stage
Peak Stage (feet on gage)
Precipitation: P (inches)
0
5
10
15
20
25
30
1
2
3
4
5
6
7
8
9
10

April 1950

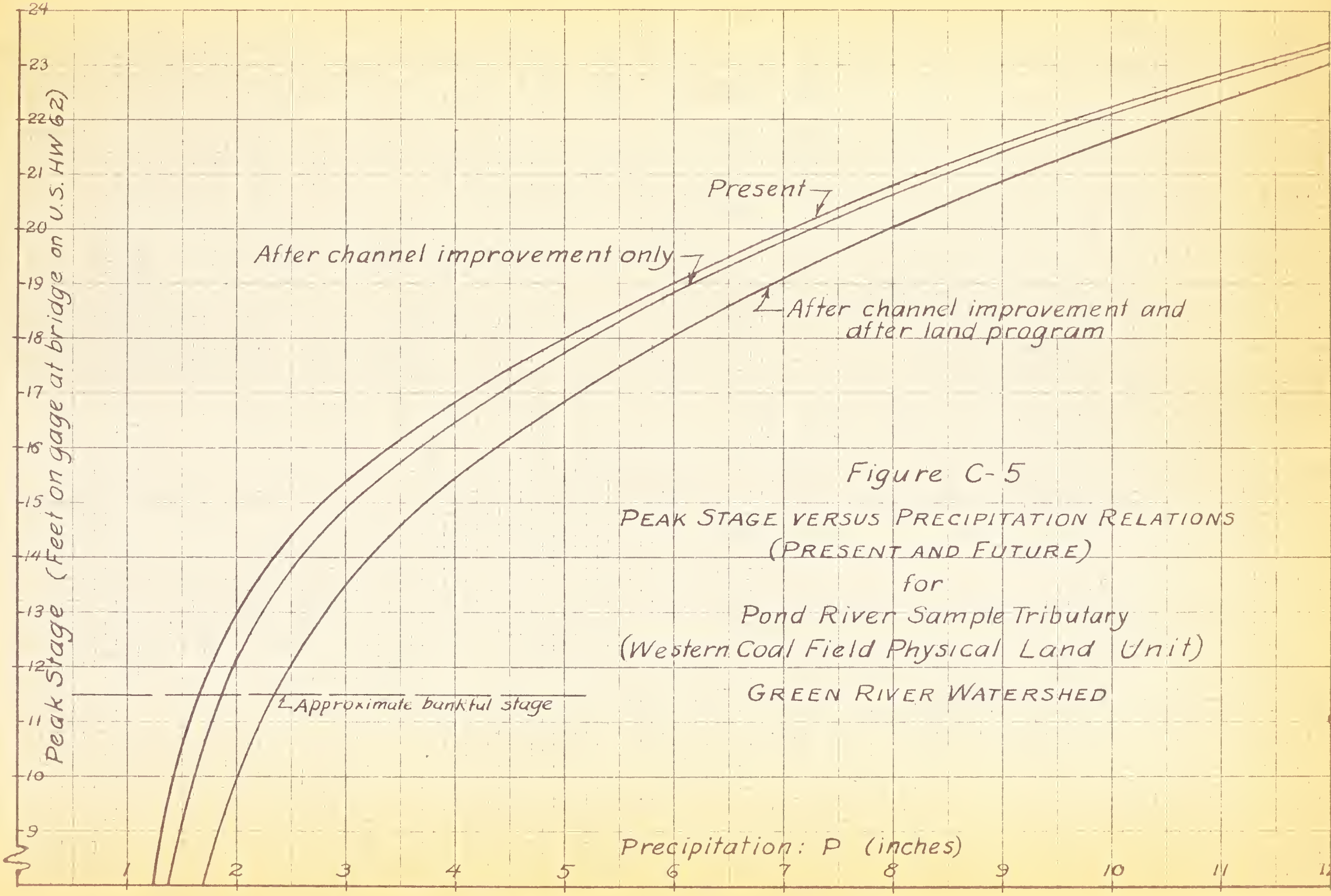


Figure C-5

PEAK STAGE VERSUS PRECIPITATION RELATIONS
(PRESENT AND FUTURE)
for
Pond River Sample Tributary
(Western Coal Field Physical Land Unit)
GREEN RIVER WATERSHED

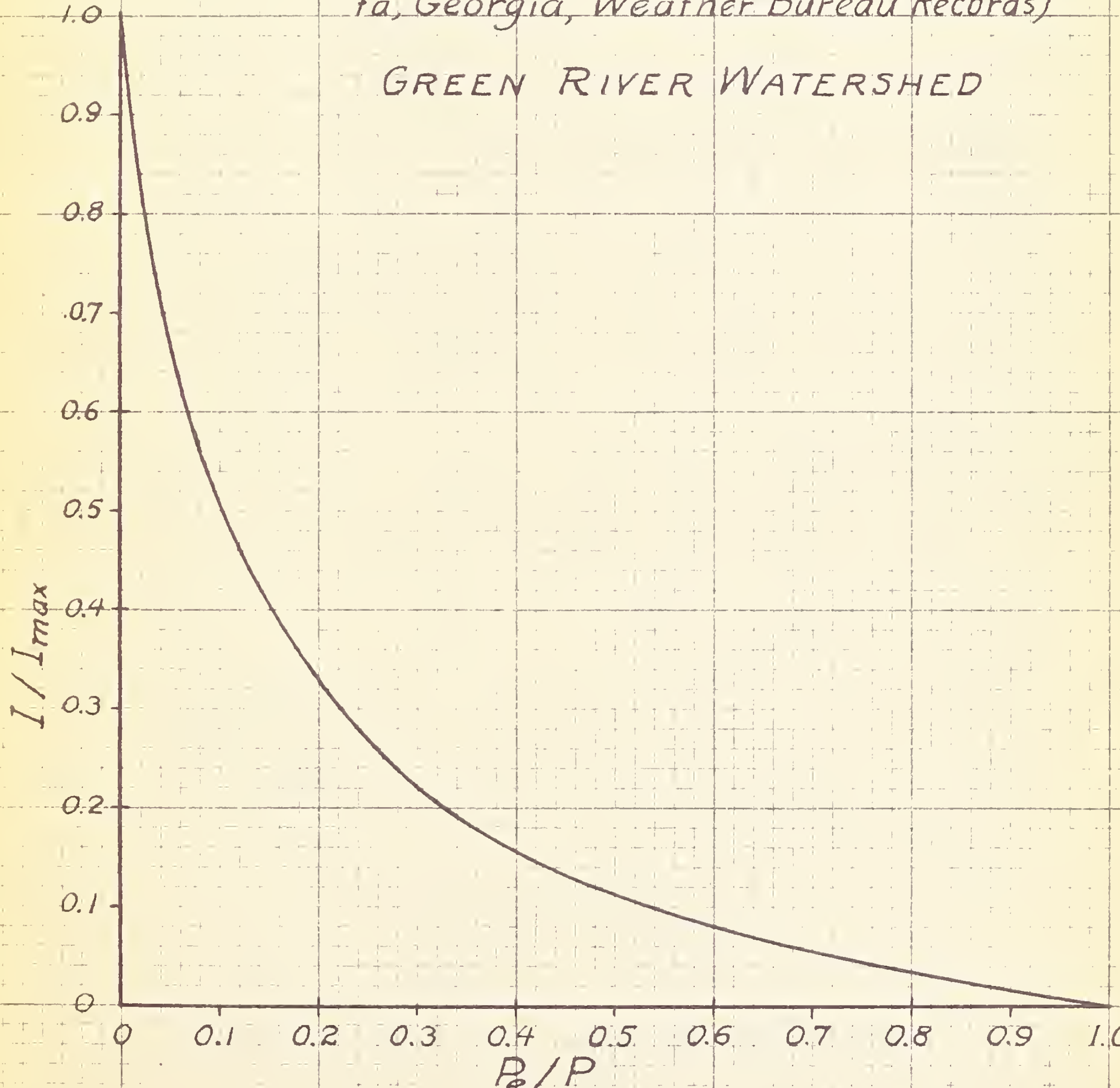
Figure C-6

DIMENSIONLESS DIAGRAM

I/I_{max} versus P_e/P Relation

(Average dimensionless diagram based on an analysis of 10-year simultaneous rainfall records from Chattanooga, Tennessee, and Atlanta, Georgia, Weather Bureau Records)

GREEN RIVER WATERSHED



April 1950

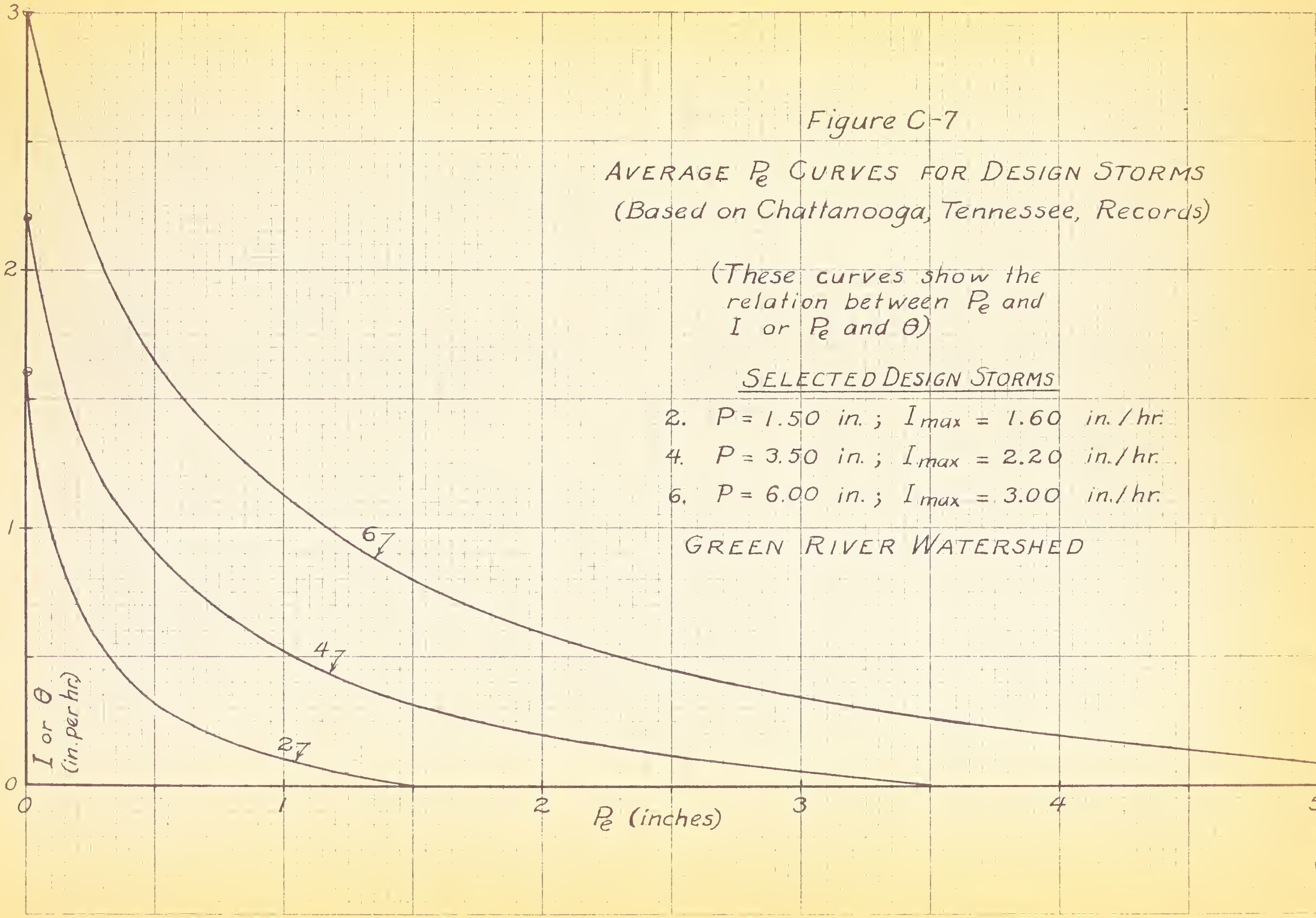


Figure C-7
AVERAGE Pe CURVES FOR DESIGN STORMS
(Based on Chattanooga, Tennessee, Records)
(These curves show the relation between Pe and I or Pe and θ)
SELECTED DESIGN STORMS
2. P = 1.50 in.; I max = 1.60 in./hr.
4. P = 3.50 in.; I max = 2.20 in./hr.
6. P = 6.00 in.; I max = 3.00 in./hr.
GREEN RIVER WATERSHED
6
4
2
I or θ (in. per hr.)
Pe (inches)
0
1
2
3
4
5

Figure C-8

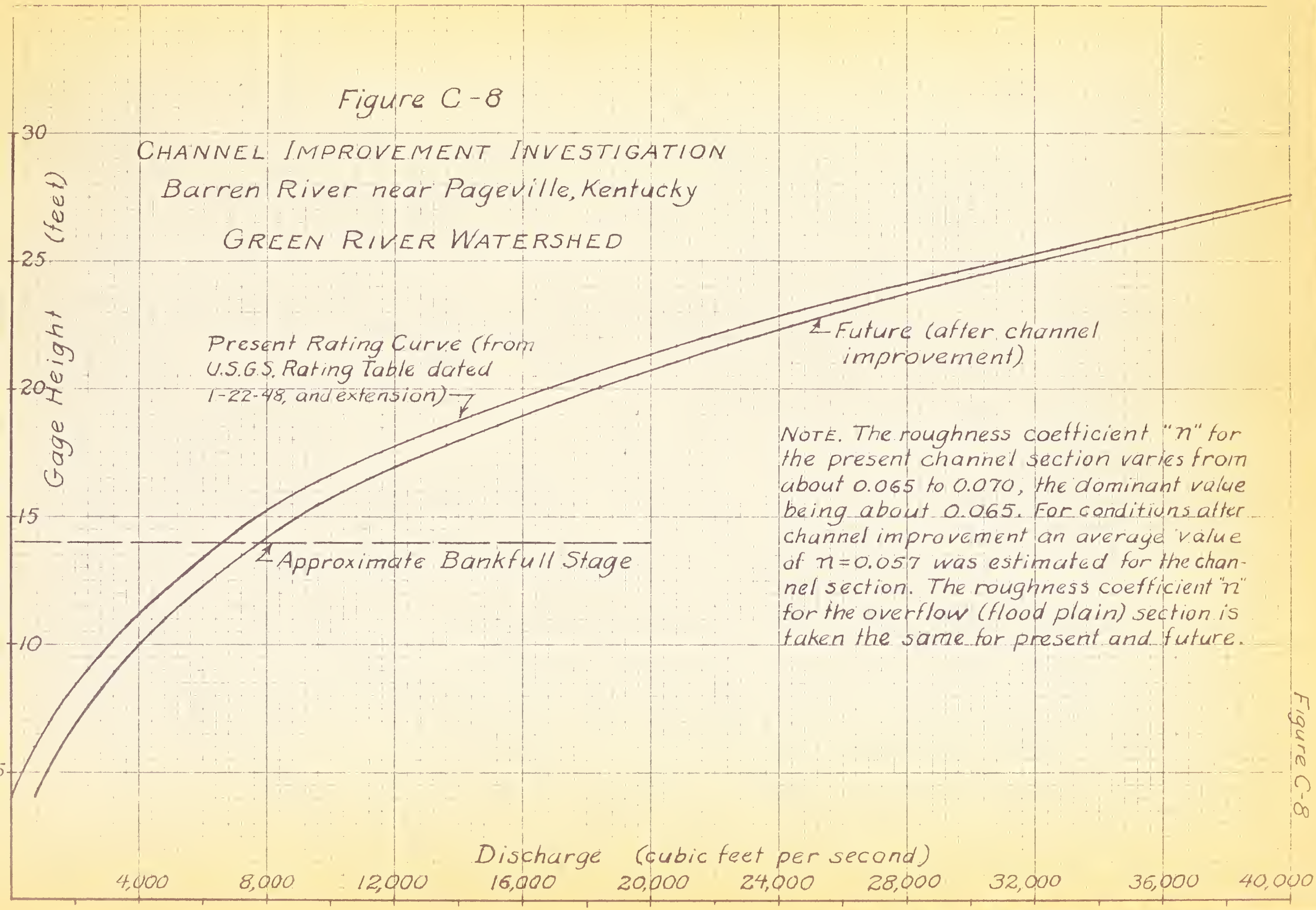


Figure C-8
CHANNEL IMPROVEMENT INVESTIGATION
Barren River near Pageville, Kentucky
GREEN RIVER WATERSHED
Present Rating Curve (from U.S.G.S. Rating Table dated 1-22-48, and extension)
Future (after channel improvement)
Approximate Bankfull Stage
NOTE. The roughness coefficient "n" for the present channel section varies from about 0.065 to 0.070, the dominant value being about 0.065. For conditions after channel improvement an average value of n=0.057 was estimated for the channel section. The roughness coefficient "n" for the overflow (flood plain) section is taken the same for present and future.
Gage Height (feet)
30
25
20
15
10
5
Discharge (cubic feet per second)
4,000
8,000
12,000
16,000
20,000
24,000
28,000
32,000
36,000
40,000

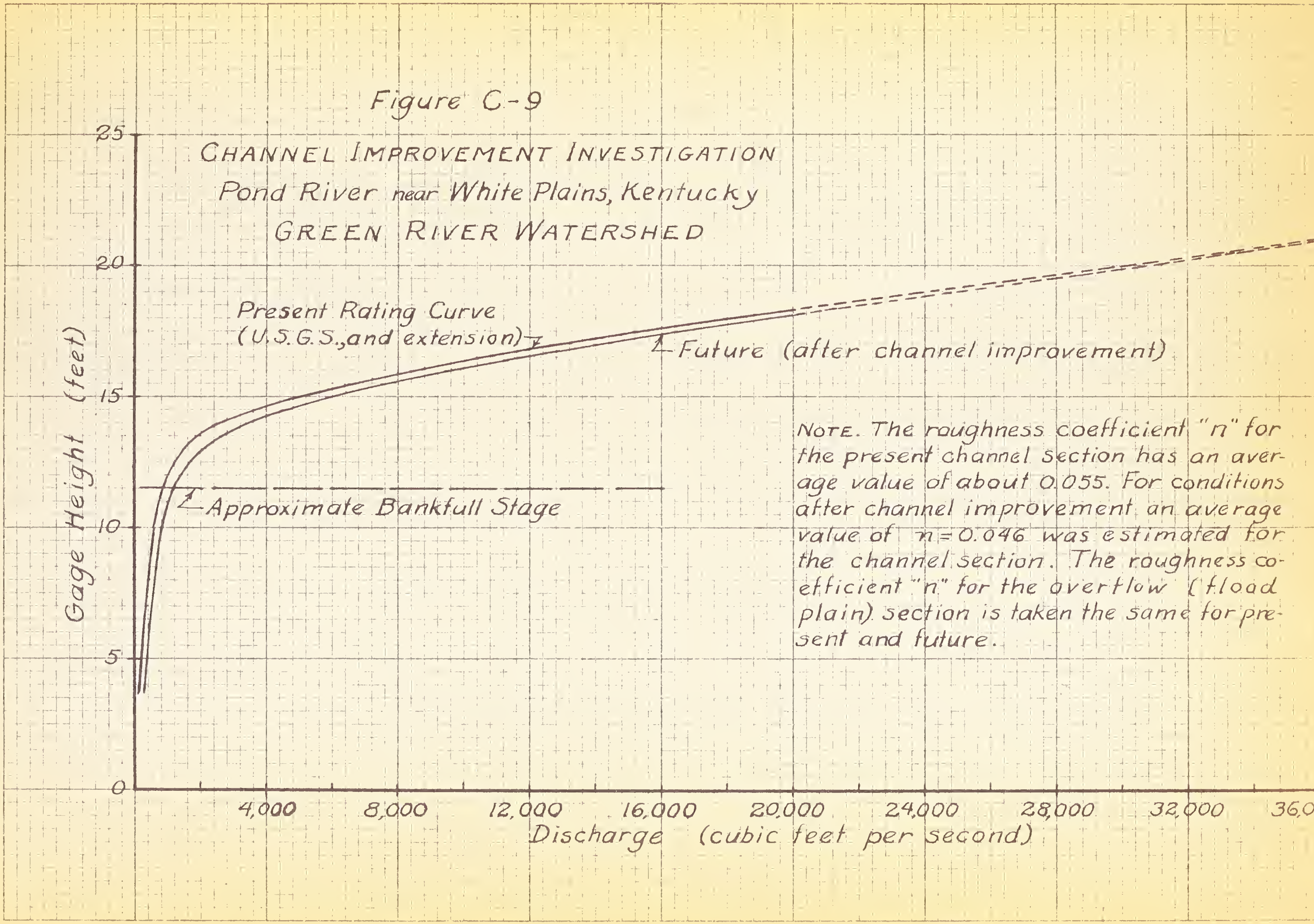


Figure C-9
CHANNEL IMPROVEMENT INVESTIGATION
Pond River near White Plains, Kentucky
GREEN RIVER WATERSHED
Present Rating Curve
(U.S.G.S., and extension)
Future (after channel improvement)
Approximate Bankfull Stage
NOTE. The roughness coefficient "n" for the present channel section has an average value of about 0.055. For conditions after channel improvement an average value of n = 0.046 was estimated for the channel section. The roughness coefficient "n" for the overflow (flood plain) section is taken the same for present and future.
Gage Height (feet)
0
5
10
15
20
25
4,000
8,000
12,000
16,000
20,000
24,000
28,000
32,000
36,000
Discharge (cubic feet per second)

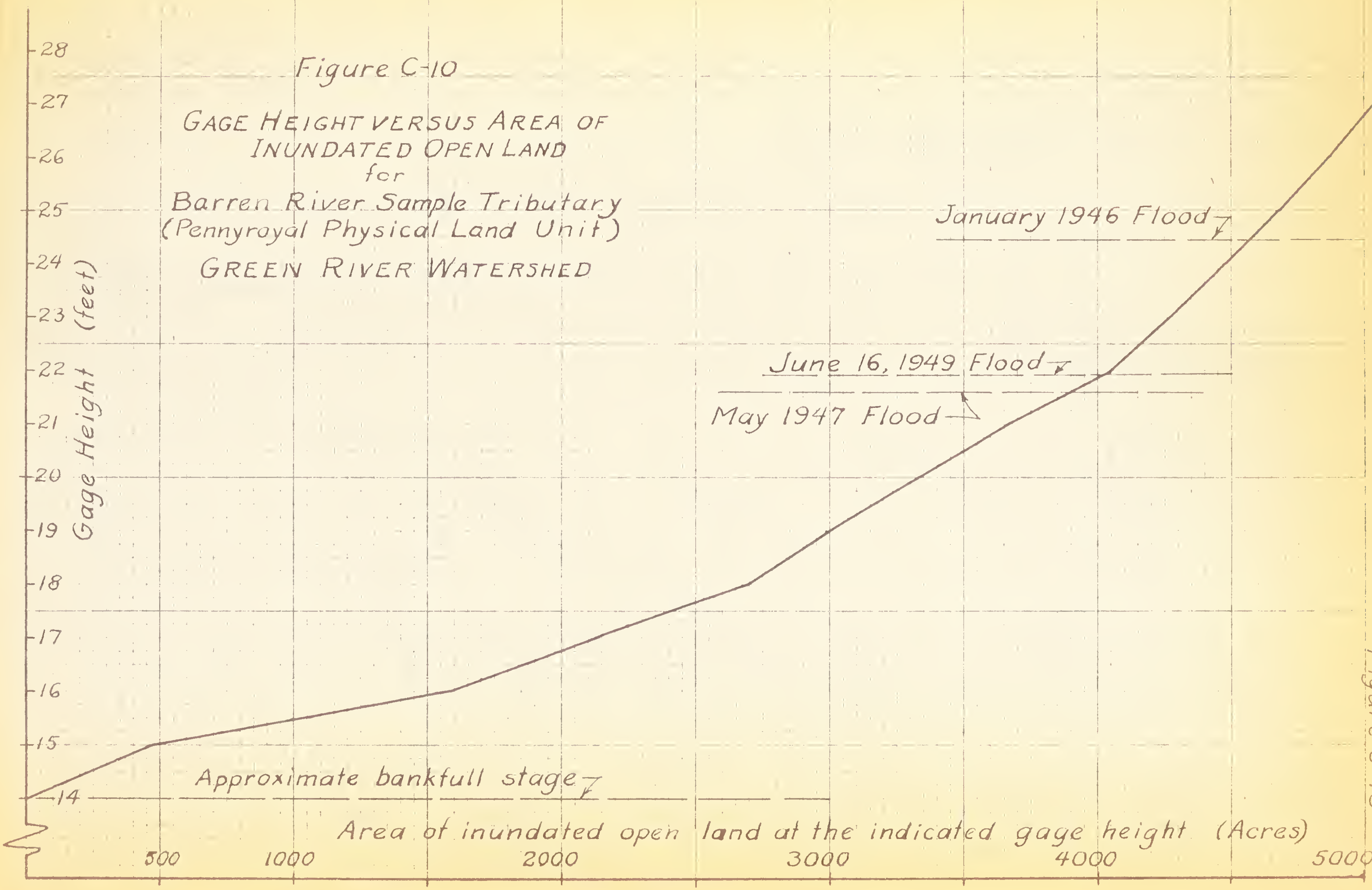
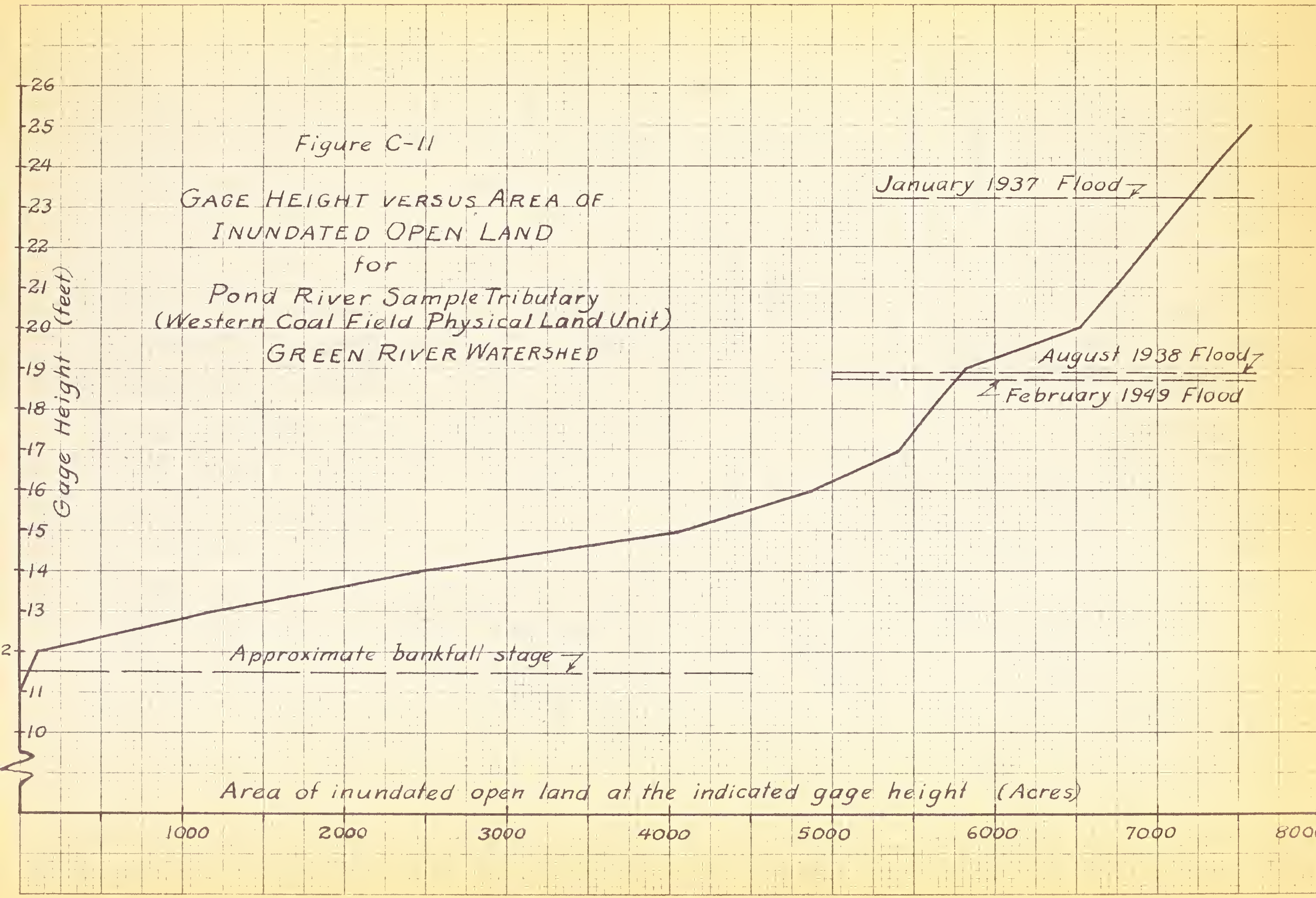


Figure C-10
GAGE HEIGHT VERSUS AREA OF INUNDATED OPEN LAND for Barren River Sample Tributary (Pennyroyal Physical Land Unit) GREEN RIVER WATERSHED
Gage Height (feet)
28
27
26
25
24
23
22
21
20
19
18
17
16
15
14
January 1946 Flood
June 16, 1949 Flood
May 1947 Flood
Approximate bankfull stage
Area of inundated open land at the indicated gage height (Acres)
500
1000
2000
3000
4000
5000

April 1950

Figure C-11



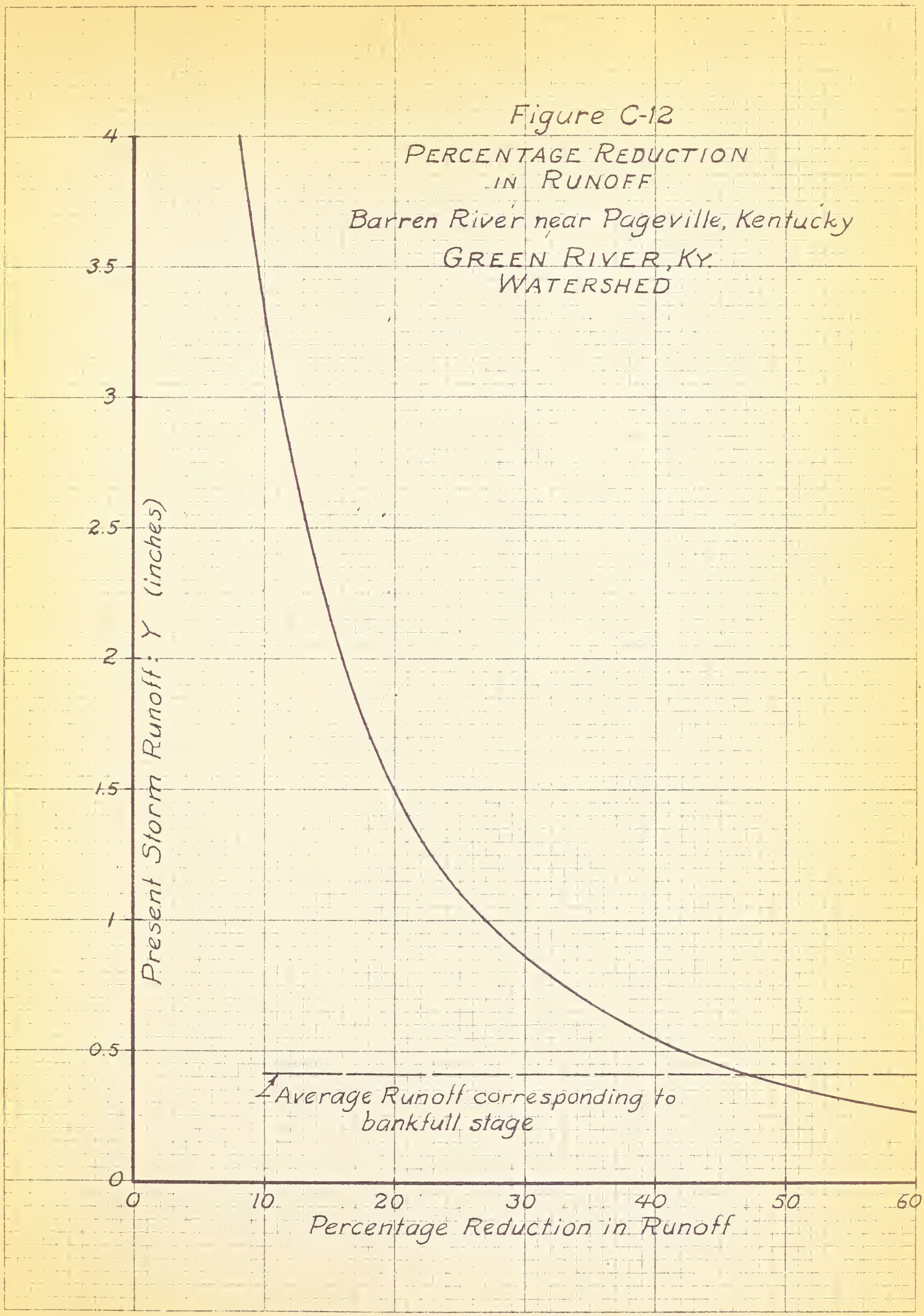


Figure C-12
PERCENTAGE REDUCTION IN RUNOFF
Barren River near Pageville, Kentucky
GREEN RIVER, KY. WATERSHED
Present Storm Runoff: Y (inches)
4
3.5
3
2.5
2
1.5
1
0.5
0
Average Runoff corresponding to bankfull stage
0
10
20
30
40
50
60
Percentage Reduction in Runoff

April 1950

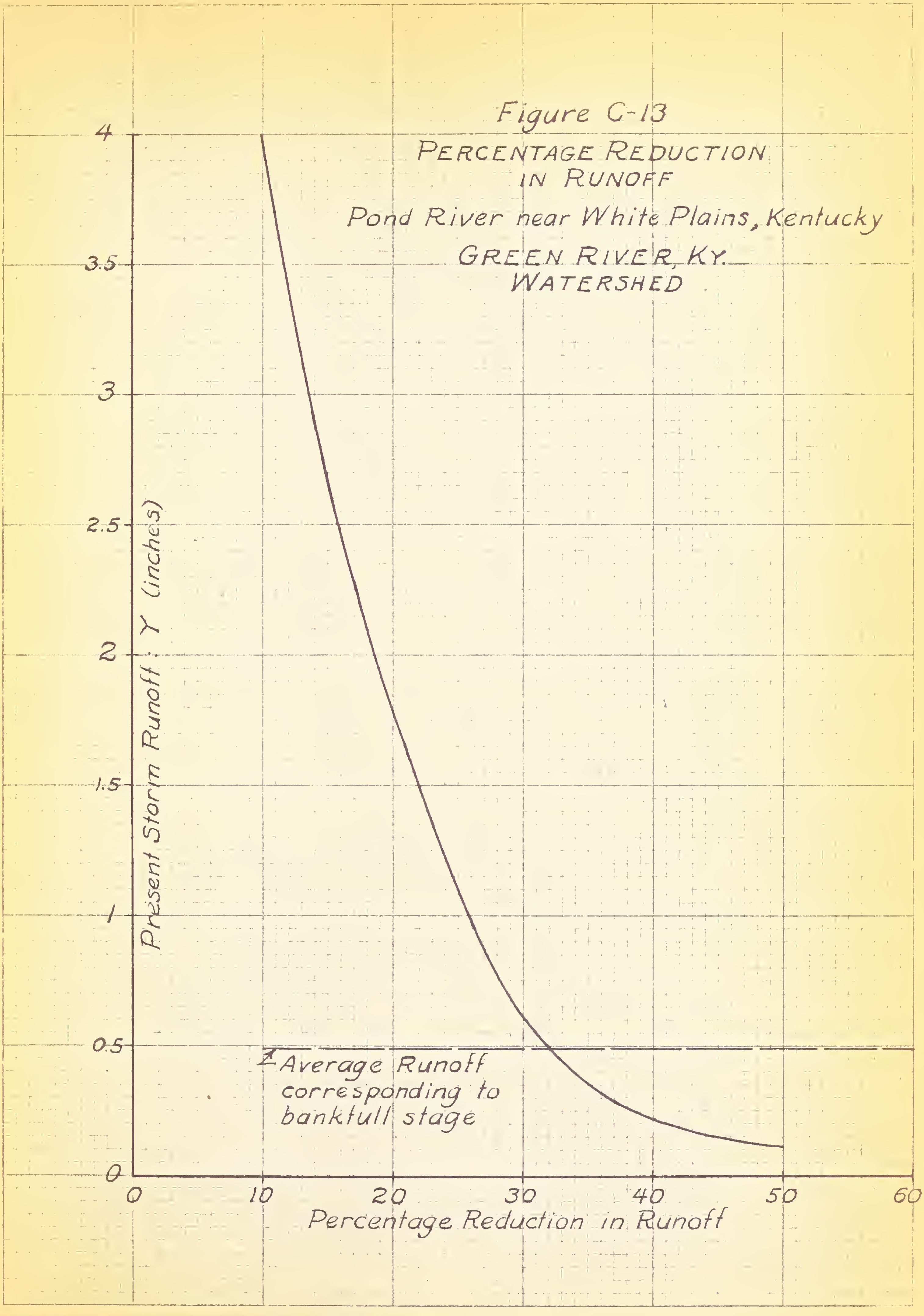


Figure C-13
PERCENTAGE REDUCTION IN RUNOFF
Pond River near White Plains, Kentucky
GREEN RIVER, KY. WATERSHED
Present Storm Runoff: Y (inches)
4
3.5
3
2.5
2
1.5
1
0.5
0
0
10
20
30
40
50
60
Percentage Reduction in Runoff
Average Runoff corresponding to bankfull stage

April 1950

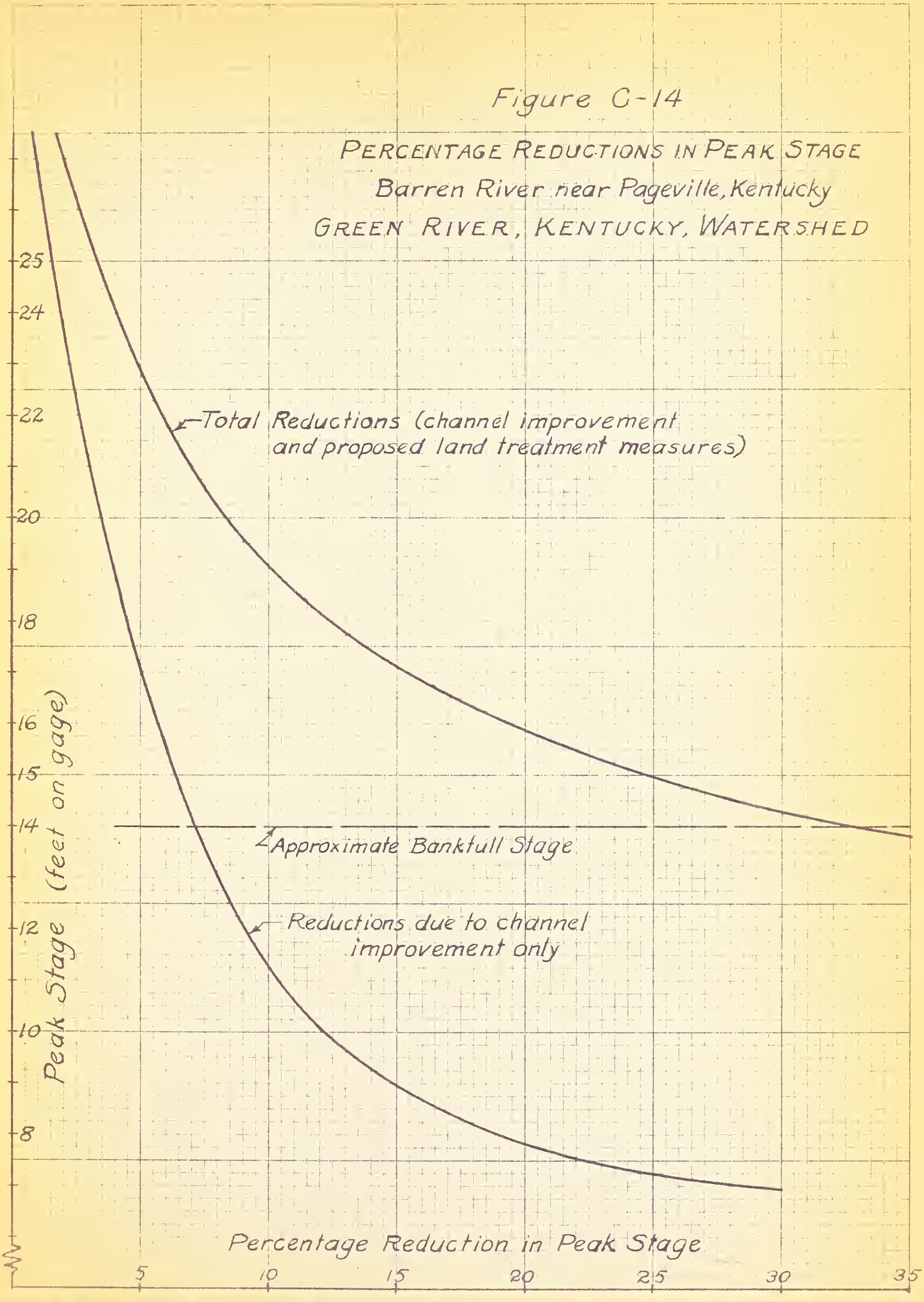
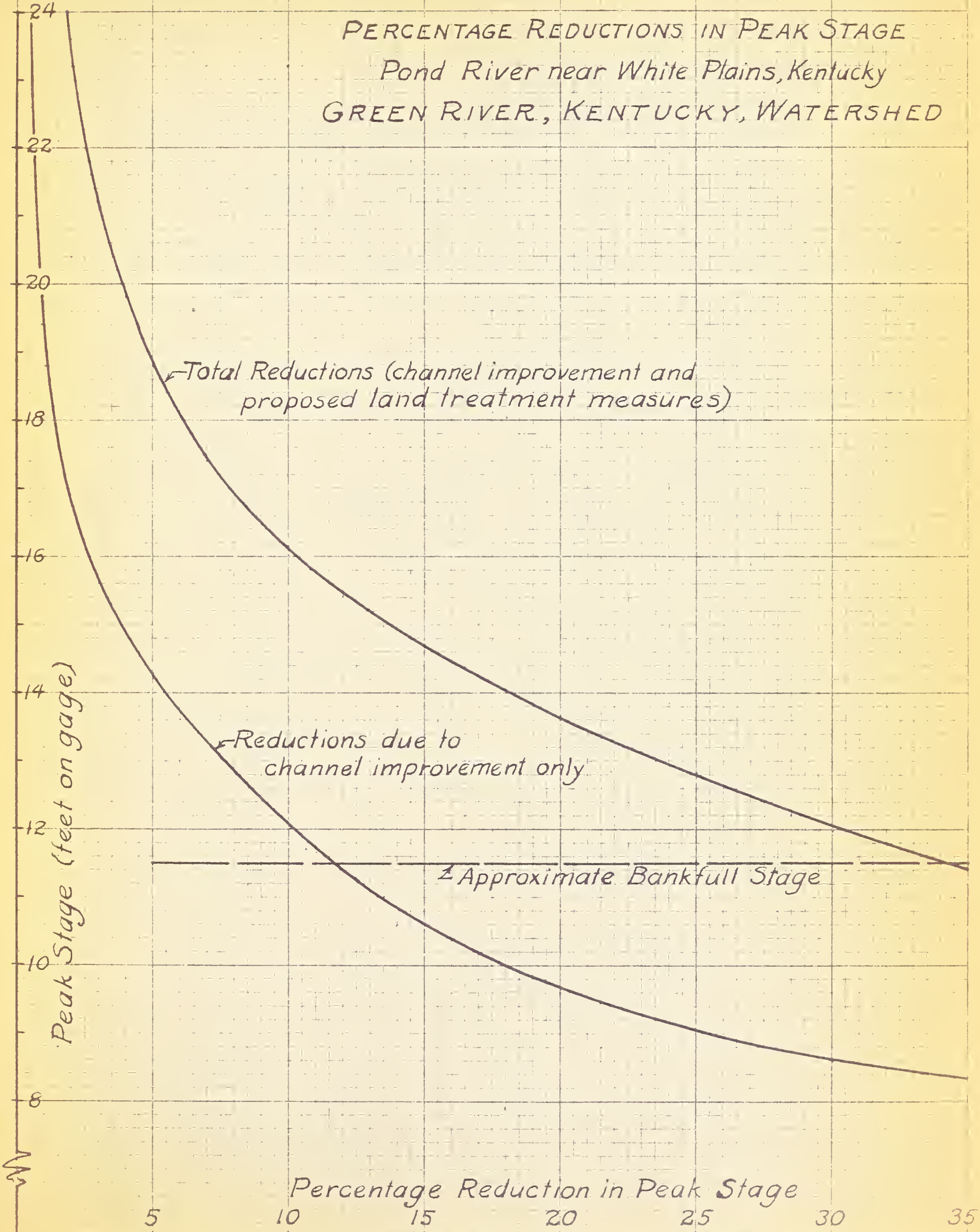


Figure C-14
PERCENTAGE REDUCTIONS IN PEAK STAGE
Barren River near Pageville, Kentucky
GREEN RIVER, KENTUCKY, WATERSHED
Total Reductions (channel improvement and proposed land treatment measures)
Approximate Bankfull Stage
Reductions due to channel improvement only
Peak Stage (feet on gage)
Percentage Reduction in Peak Stage
25
24
22
20
18
16
15
14
12
10
8
5
10
15
20
25
30
35

Figure C-15

PERCENTAGE REDUCTIONS IN PEAK STAGE
Pond River near White Plains, Kentucky
GREEN RIVER, KENTUCKY, WATERSHED



April 1950

APPENDIX D

DAMAGES, BENEFITS AND COSTS

TABLE OF CONTENTS

Tables

PART I - FLOOD WATER AND SEDIMENT DAMAGES AND BENEFITS

FLOOD WATER DAMAGES

Introduction

Damage investigations on the Green River Watershed were conducted on sample tributary streams. Barren River in Kentucky was used as the hydrologic sample representing the Pennyroyal area. Pond River in Kentucky was used as the hydrologic sample for the Western Coal Field area. Other tributary samples were used in both Physical Land Units to adjust land use and yields of the hydrologic samples, as proven necessary by field investigation.

No damage estimates were made on the main stem below the Western Coal Field-Pennyroyal boundary as little or no benefits could be claimed for reduction of damages below this point on the main stream by a watershed treatment program. Since the upper part of the main stem above the Western Coal Field-Pennyroyal boundary is comparable to the sample tributaries, it was treated as a tributary in the general estimate of damages and damage reductions.

Since flood water damages on the Green River tributaries are largely agricultural, the investigations had to do largely with crop, pasture, fixed improvement, and land damages. Estimates were obtained from state highway departments and railroads as to the damages to public roads and railroads. All estimates are based on 1948 prices.

General Procedure and Methods

Farmers owning or operating crop and pasture land within the flood plain of sample tributaries were interviewed to obtain detailed information. Information obtained included land use distribution within the flood plain, average yields of crops and pasture when not damaged by floods, and percent damage by depths of inundation by seasons for individual crops and pasture when flooded. Further observations and contacts were made along each sample tributary and other tributaries to supplement, check, and adjust where necessary, the information gained from individual farmers on the hydrologic samples. Much useful information of recent origin was obtained from the University of Kentucky, College of Agriculture, and the Kentucky Agricultural Statistician's Office on the cost of producing various crops, prices received by farmers in 1948 and practices applicable to the areas being studied. After costs of producing individual crops per acre by Physical Land Units were computed, using the information obtained from all sources, they were submitted to the Farm Economics Department, University of Kentucky, for comment. The experience of local agricultural field workers served as a guide in obtaining adequate local information in the watershed.

Flooded areas were outlined on aerial photographs for two floods of record on each sample tributary and the extent of each flood was planimetered to determine total area within the flood plain as related to the average peak flood stage. The area of open land and woodland within the flood plain was determined in the same way.

Damageable Values Per Acre

Damageable values per acre for each crop grown in the flood plain were estimated for each month of the year by Physical Land Units. Following this, a weighted average damageable value by months for all crops grown on a composite acre of open flood plain land was computed. Examples of these two steps in estimating damages are found in Tables D-1 and D-2.

In Table D-1 the values are mid-month averages per acre for each crop grown in the flood plain. In Table D-2 the values from Tabld D-1 have been weighted by the proportionate area of open flood plain land each crop occupies to give a total damageable value for a composite acre of open flood plain land.

Seasonal Damage by Depths of Inundation

Estimates were obtained from selected farmers having considerable experience in growing crops in the flood plain concerning the percent damage resulting from floods of varying depths to various crops for each month of the year. These estimates were adjusted to a reasonable figure for use in making estimates of damages per acre by depths of inundation for the various crops. They were then checked against estimates (made by farmers in the same general area) of monetary damages from specific floods and with data obtained on other watershed studies where similar conditions prevail. The percentage estimates were used in computing a weighted average damage per acre for all crops by depths of inundation. See Tables D-3 and D-4 for examples of the procedure used in this computation. Percentages in Table D-3 multiplied by corn values by months in Table D-2 give damages to corn by depth of inundation by months as shown in Table D-4.

Damages by depth of inundation and by months were computed for each crop (including pasture) grown in the flood plain. These were summarized to give flood damages to crops and pasture per acre of open flood plain land by months and by depth of inundation as shown in Table D-5. The same general procedure was used in computing damages to fixed improvements except that it was not necessary to vary damages to fixed improvements by months. It was recognized that there would be some differences in the nature of damages to fixed improvements between the summer and winter seasons. But, all factors considered, the differences in dollar damages would be negligible.

Stage-Area by Depth of Inundation Relationship

The area of land inundated by any flood stage by one foot intervals of inundation was determined from valley cross-sections, taken at appropriate intervals, elevations of the flood line for two floods of record varying widely in stage, and planimeter work on aerial photographs of the sample tributary stream. The open land flooded at one foot depth of inundation intervals was then determined from the aerial photographs by proportion. Field studies indicated that no corrections were necessary in the area of open flood plain land as determined by planimetering aerial photographs. The acreage of land being cleared is approximately equal to that reverting to forest cover.

A summary of the acres of open flood plain land inundated by one foot depth of inundation intervals for each foot difference in the average peak flood stage is shown in Table D-6. For expansion purposes, this acreage table was calculated on a stream mile basis by dividing the total acres of open flood plain land inundated by the stream mile length of the sample tributary stream.

Stage-Damage Relationship

Tables indicating stage-damage relationships per stream mile were prepared for each sample tributary. To obtain the crop and pasture damage per stream mile on a sample tributary for a given month and stage height, the areas inundated per stream mile at various depths of inundation for a given stage height (Table D-6) were multiplied by the amount of damage per acre for the respective depths of inundation (Table D-5). The sum of these damages amounts to the crop and pasture damage per stream mile for a flood of given stage height. Stage-damage relationships for the Pennyroyal area sample tributary are shown in Table D-7.

Average Annual Agricultural Damages Per Stream Mile

Average annual flood damages per stream mile were computed for each sample tributary by adding the damages per mile resulting from each flood during the period of record and dividing by the number of years in the period.

Floods during the period of record were listed chronologically giving the date and the average peak stage of each flood (Tables C-2 and C-3, APPENDIX C, HYDROLOGY). For each flood of record, the agricultural damage was obtained from the table showing stage-damage relationships (Table D-7) and adjusting for sequent flooding.

When more than one flood occurs within a given season of the year, all floods occurring in that season after the first flood are called sequent floods. Each sequent flood will do proportionately less damage to the acreage previously inundated than did any preceding flood of the season. This is taken into consideration to avoid overestimation of damages.

The estimated average annual agricultural damages per stream mile without a program (present damages) for the various sample tributaries in each Physical Land Unit are as follows: Pennyroyal area (Barren River hydrologic sample), $1,050; Western Coal Field area (Pond River hydrologic sample), $1,633 (Table D-8).

Agricultural Damages With Channel Improvement Only and With a Complete Program

In estimating future damages with channel improvement only and with a complete program, the land use and damageable values on the flood plain were assumed to remain the same as that used in estimating present damages. Estimates of reduction in agricultural losses result from reductions in average peak stages and area inundated.

The estimated average annual damages per stream mile in the future with channel improvement only by sample tributaries in each Physical Land Unit are as follows: Pennyroyal area, $833; Western Coal Field area, $1,386. A complete program, including channel improvement, is expected to reduce these damages to: Pennyroyal area, $582; Western Coal Field area, $932.

Total damages for each Physical Land Unit (present, with channel improvement only, and with a complete program) were obtained by multiplying the amount of the average annual damage per stream mile by the number of miles of streams subject to flooding. Estimated total agricultural damages with a complete program, with channel improvement only, and without a program are shown in Table D-8 by Physical Land Units for the Green River Watershed.

Damages to Roads and Railroads

Estimates were obtained from the state highway departments in Kentucky and Tennessee on the annual flood damages sustained on roads and bridges within the Green River Watershed.

Similar estimates were obtained for railroad property from officials of the Illinois Central Railway Company. A summary of the estimated annual damages and benefits to public roads and railroads within the watershed is shown in Table D-9.

Other Damages

Since damages and damage reductions to farm buildings and tile drains were negligible, damages to these items are not included in the damage estimates. Damages to other fixed improvements were incorporated in the agricultural damage estimates.

Occasional damage to livestock, poultry and equipment occurs but is of small consequence, therefore, no estimate was made of such damages.

Intangible Damages

Loss of life resulting from floods has been low in the Green River Watershed. Illness due to floods has not been a serious problem.

There are additional indirect damages that are not of a physical nature but are the result of floods. Such damages are the loss of business, loss of wages, disruption of public utility services and transportation, loss of rent, and costs of relief and sanitation. No attempt was made to evaluate these damages. An example of this type of damage is found in a small community near Barretts Ferry, Kentucky, where traffic is reported as being stopped by floods an average of five times per year for periods averaging about five days each. During the winter of 1948-49 the school bus, mail service, and other traffic was stopped for one week at one time. Traffic was reported stopped ten times during this same winter season for periods varying from three to seven days.

SEDIMENT AND RELATED DAMAGE

Sediment Damage to Flood Plain

Western Coal Field Physical Land Unit

The lower Green River Watershed is characterized by very extensive flood plains. These broad, alluvial valleys were formed during glacial times when heavily silt charged backwater and ponded water from melting ice filled the valleys with glacial outwash material. In some places the depth of the alluvial deposits is more than 100 feet. These wide alluvial bottoms extend upstream for about a third of the length of the watershed.

Bottom lands make up a large portion of the total land area in Daviess, Henderson, and McLean Counties. It was estimated that during the 1937 flood approximately 55 percent of McLean County was inundated. Smaller floods of more frequent occurrence may cover as much as one-third of the county. Flood plains along the Green River sometimes reach 6 to 8 miles in width, while those along the smaller tributaries may be as much as a mile wide. Bottom lands make up 20 percent of the total Physical Land Unit.

In its lower reaches the Green River is essentially a graded stream. The channel is free from major obstructions. The banks are high, heavily vegetated with trees and brush and relatively stable. Recently there has been considerable bank caving and sloughing but there is no evidence of permanent widening of the channel section.

Studies by the Corps of Engineers, Department of the Army, of the Green River show a low rate of channel fill. In 1930 several channel sections were made above the navigation dams. These were compared with sections made in previous years. It was found that the rate of sediment deposition was 0.04 feet per year. 1/

Channel conditions on the tributary streams in the lower third of the watershed are generally poor. The channel sides are grown up in overhanging trees and brush. In the summer months during periods of low discharge, willows become established in the channel bottoms. Willows, snags, drift heaps, and mud bars obstruct the channels in many places. Low gradients and tortuous courses contribute to the poor channel conditions. Stream channels on Pond River, the lower reaches of Mud River, and Rough River and its tributaries below the Falls of Rough have badly clogged channels.

Channel conditions are generally good on streams extending beyond the broad alluvial valleys of the lower watershed. Gradients are relatively steep and controlled by bed rock. Channel bottoms are rock ledge and gravel. Flood plains are usually narrow but occasionally become fairly extensive in the headwater areas. Except for occasional snags and gravel bars the streams are maintaining adequate channels.

1/ House Document No. 81, 73rd Congress, 1st Session, Green, Barren, and Rough Rivers, Kentucky, 1932.

Damage to flood plains from deposition of coarse sediment is of minor importance as the streams carry very little coarse material. Deposition, however, takes place with almost every flood. Discovery of buried fences in some of the lower tributary valleys indicates deposits of modern origin many feet in depth. The bulk of the sediment being deposited is made up of fine silt from eroding loess uplands. This material differs very little from the pre-modern deposits. Damage is negligible although some farmers claim that the more recent deposits are not as productive as formerly. The texture of the bottom soils is usually silt loam with some fine sandy loams adjacent to the channels. Some sanding occurs on the upper reaches of the Rough and Nolin Rivers but it is of very limited extent.

With the exception of those bottom lands lying adjacent to the Green River, the wide flood plains in the lower third of the watershed are inherently poorly drained. These bottoms often remain under water for long periods during the winter months. Extensive agricultural development of these lands did not begin until about 50 years ago when improved farm machinery made it possible to prepare the land quickly late in the season. 1/

Swamping, or raising of the water table under bottom lands, brought about by badly obstructed or filled channels, is causing serious damage to flood plains which have been artificially drained. Vegetation growing or lodged in the channel is a major contributing cause of poor channel conditions.

Scour damage affects less than one percent of the total flood plain area. Except for occasional overflow channels cut into the flood plain, damage from scour is negligible. Overflow velocities on the larger bottoms are usually not sufficient to cause serious flood plain erosion.

Although tributary stream banks are generally heavily vegetated and relatively stable, a considerable amount of localized stream bank erosion occurs.

There are extensive strip mined areas in Hopkins, Muhlenberg, and Ohio Counties. Some of the strip mining dates from World War I but much of it is recent. These operations are affecting a constantly increasing area of bottom land. "Copperas" water and outwash debris from the spoil banks have caused serious damage to nearby flood plains. Damage from this source is expected to become more extensive as more outwash materials get into the stream channels.

The streams used to represent the lower portions of the Physical Land Unit on the detailed sediment damage survey were reaches of Green River, Long Falls Creek and Cypress Creek. Streams used as samples of the upper portions of the Physical Land Unit were the Upper Pond River, Caney Creek, and reaches of the Rough River.

1/ Bureau of Soils, U. S. Dept. of Agriculture, Soil Survey of Muhlenberg County, Kentucky, 1924.

Pennyroyal Physical Land Unit

Flood plains in the Pennyroyal Physical Land Unit are much less extensive than in the lower portions of the watershed and make up approximately 4 percent of the total land area.

The courses of the Green River and its principal tributaries, throughout most of their length, follow tortuous entrenched meanders. Channel bottoms are rock ledge and gravel and are controlled by bed rock. Stream banks are steep, relatively high and are usually heavily vegetated. The stream bottom soils are predominantly fertile, well to imperfectly drained silt loams and largely in cultivation. Corn is the principal crop.

The upland soils do not contain much sand and relatively small amounts of coarse erosional debris are contributed to the stream channels by erosion. Except for occasional gravel bars and snags, the stream channels in this section are in good condition and are maintaining adequate discharge capacities.

Damage from deposition of sterile sediment is small as the streams carry very little coarse material. There are occasional chert and gravel deposits of pre-modern origin along Barren River. Little Barren River carries some sand and there are occasional sandy spots on the flood plain.

Scour damage to flood plain land sometimes occurs but the amount of permanent damage from this source is small. Scour is most prevalent along the Barren River and its tributaries. The sediment damage survey showed 0.7 percent of the total flood plain in the area damaged by scour.

Swamping and stream bank erosion are minor problems in the Pennyroyal Physical Land Unit.

The sample streams used to represent the Pennyroyal Physical Land Unit on the sediment damage survey were reaches of Barren River, Skeggs and Peters Creeks in Barren County, reaches of Green River, Little Barren River, and Brush, Russell and Pitman Creeks in Green County.

Although sediment and related damages to flood plains in the Green River Watershed are recognized, the nature of the storms causing this type of damage is such that the expected damage reductions due to a watershed treatment program would be negligible. Therefore, no monetary evaluation of these types of damages was made.

Method of Making Flood Plain Sediment Damage Surveys

At the beginning of the survey a reconnaissance was made of the entire watershed to determine the general extent and seriousness of the sedimentation problem. Following this, the sample areas were selected for detailed study. Detailed sediment damage surveys were made on sample tributaries and reaches within each Physical Land Unit. Aerial photographs with a scale of 1 inch = 1320 feet and aerial photograph index sheets with a scale of 2 inches = 1 mile were used as a base.

The purpose of this mapping was to show the extent of physical changes in the flood plain resulting from accelerated sedimentation and related damages. A three place symbol was used to show, in a roughly quantitative manner, the several types of sediment damage.

The first of these variables indicated the extent of modern deposits of infertile sediment on the flood plain. The second symbol represented swamping, the result of channel fill and subsequent raising of the water table under adjacent bottom lands. The third damage was scour, the cutting of channels or removal of bottom soils by flood water.

The following legend was used when making the sediment damage studies:

Deposition of Infertile Sediment:

1 = 0-33 percent of area covered by sand to depths of 8 inches or more.

2 = 33-67 percent of area covered by sand to depths of 8 inches or more.

3 = 67-100 percent of area covered by sand to depths of 8 inches or more.

Swamping:

1 = Bottom land formerly suitable for cultivation, now suitable only for woodland.

Scour:

1 = 0-33 percent of area scoured to depths of 12 inches or more.

2 = 33-67 percent of area scoured to depths of 12 inches or more.

3 = 67-100 percent of area scoured to depths of 12 inches or more.

Reservoir Sedimentation

No large retention type reservoirs are located in the Green River Watershed.

Six navigation dams, with locks, are located on the Green River; one on Barren River. Small milldams are located at Dundee, Falls of Rough and Hardin Springs, Kentucky, on the Rough River. A few other small milldams are found in the watershed. All of these structures are low head, channel type dams.

The only retention type reservoirs are three small water supply reservoirs on Clear Creek in Hopkins County, Kentucky, and a few other small water supply and recreational reservoirs scattered over the watershed. All of these structures represent small initial investments. Benefits from reductions in the rate of sedimentation are negligible.

There have not been any reservoir sedimentation surveys made in the watershed but rates of sediment production are expected to be high. Reconnaissance investigations of a number of reservoirs outside the watershed but in comparable physiographic areas show average annual rates of sediment production varying from 0.5 to 4.0 acre-feet of sediment per square mile of drainage area.

The Corps of Engineers estimated the rate of silt production in the Rough River Watershed at about 0.3 acre-feet of sediment per year per square mile of drainage area. 1/

Sediment Damage to Public Water Supply

During 1948 about 2.7 billion gallons of water were filtered for domestic and industrial use in the Green River Watershed. Twenty-two filtration plants were in operation. Most of the plants were small. The largest, Bowling Green, Kentucky, treated 889 million gallons during the year.

Most of the plant operators reported moderately high turbidities during the growing season; low turbidities during the remainder of the year.

Turbidity measurements at the Franklin, Kentucky, plant showed very low turbidities (10-14 ppm) during much of the year. This plant is supplied with water from the headwaters of Drakes Creek which is largely spring fed. Turbidity measurements taken at the raw water intake of the Central City, Kentucky, plant, which is supplied by the Green River, gave turbidities varying from 50 to 1500 ppm.

Greenville depends entirely on a rainfall catchment basin connected to a small storage reservoir for water supply. The Auburn, Elizabethtown, and Horse Cave plants are supplied from ground water. However, in these cases ground water is considerably influenced by surface runoff and requires filtration. Most of the filtration plants do not have retention reservoirs and depend entirely on run-of-stream.

Cost of treatment figures, when available, were usually not itemized. Estimates were used whenever water demand and cost figures could not be obtained.

Effect of the Recommended Program on Public Water Supply

A large part of the cost of water treatment is attributed to fine suspended matter which is largely a direct product of soil erosion. The recommended program will reduce the cost of water treatment by reducing stream turbidities. The largest saving will be in the use of chemicals, principally alum. Additional savings will be in labor and reduced filtering and wash water charges.

1/ House Document No. 535, 78th Congress, 2nd Session, April 13, 1944.

Because of the relatively low turbidities during much of the year, the recommended program is expected to have a limited beneficial effect. It is estimated that the recommended program will result in a 5 percent reduction in filtration costs. This figure was used when calculating benefits from the land treatment measures, Table D-10.

Other Sediment Damages Not Evaluated Monetarily

Drainage

A large part of the flood plain in the lower Green River basin requires drainage. Bed-furrows are commonly used to improve surface drainage. Currently there is considerable interest in drainage work and more lands are being drained all the time.

The following table is based on public drainage systems now in existence plus a small amount of private or community type drainage accomplished in the past two years. The figures are for the seven counties in the lower Green River basin and represent practically all the important drainage enterprises in the watershed.

DRAINAGE ENTERPRISES

Type	Length	Area Benefited	Initial Cost	Annual Maintenance
	Miles	Acres	Dollars	Dollars
Main Canals	200	145,000	1,500,000	30,000
Laterals	195	143,000	1,200,000	24,000
Tile	---	100,000	2,500,000	3,000

In the past, maintenance has been inadequate or entirely lacking. Most of the work done by the old drainage districts failed because the ditches soon filled with vegetative debris and sediment. Recently there has been more of an effort toward proper maintenance although it is still inadequate.

Navigation

The navigation project for Green River extends from the mouth to Mammoth Cave, Kentucky, a distance of 197.8 miles; for Barren River from the mouth to Bowling Green, Kentucky, a distance of 30.1 miles; for the Nolin River from the mouth to Meredith Ferry, a distance of 7.8 miles; and for Bear Creek, Kentucky, for a distance of 8 miles above its mouth. There are 6 navigation locks on the Green River; one on Barren River. 1/

1/ Annual Report of the Chief of Engineers, U. S. Army, 1948.

The estimated annual cost of maintenance of the channel on Green, Barren, and Nolin Rivers is $40,000; on Bear Creek, $500 per annum. During the fiscal year ending June 30, 1948, channel maintenance work was confined to Green and Barren Rivers. The total cost of dredging and snagging was $33,425. Approximately 450 snags were removed from the channels in the pools of the dams, and 55,150 cubic yards of material were removed from the lock chambers, approaches, and channel.

Investigations by the Corps of Engineers indicate that about 600,000 cubic yards of material will be deposited in the 260 miles of canalized river. 1/

The recommended program will reduce the amount of sediment getting into the navigation channels, thus reducing the cost of maintenance dredging. Benefits from this source are expected to be relatively small.

Miscellaneous Sediment Damages

Additional sediment damages are damages to aquatic life, forage crops, property and increased incidence of disease. In this watershed, damages from these sources are not sufficiently significant to evaluate monetarily.

SUMMARY OF DAMAGES AND FLOOD CONTROL BENEFITS

All flood water and sedimentation damages and damage reductions evaluated monetarily are summarized in Table D-11. The greatest present damages occur to crops, pasture, and fixed improvements (agricultural damages), amounting to 89.4 percent of the total estimated damages. Damages to roads and railroads amount to 7.2 percent of the total damages, and damages to water supplies from silting amount to 3.4 percent of the total damages. Anticipated reductions of all damages range from 39.0 percent in the Pennyroyal Physical Land Unit to 41.0 percent in the Western Coal Field Physical Land Unit.

1/ Chief of Engineers, U. S. Army - Green, Barren, and Rough Rivers, Ky., House Document No. 81, 73rd Congress, 1st Session, 1933.

PART II - COSTS AND CONSERVATION BENEFITS OF THE WATERSHED TREATMENT PROGRAM WITH ADJUSTMENTS FOR GOING PROGRAM COSTS

GENERAL

Appraisal of the effects of the recommended program include soil and water conservation benefits accruing to farm owners and operators as a result of the open farm land treatment program, reduction in maintenance costs of railroads and public roads due to erosion control, and increased returns on woodlands as a result of fire control and better management.

As inferred previously under the heading FLOOD WATER AND SEDIMENT DAMAGES AND BENEFITS, the recommended program will also reduce flood volume and peak discharge thereby bringing about better regulation of stream flow and reduction of flood crests. The area inundated by present floods of various magnitudes would be reduced on the tributaries and upper reaches of the main stream. It is estimated that the rate of accelerated sheet and gully erosion will be greatly reduced.

The major land use changes recommended will result in conversion of most of the idle and the steep, eroded, cultivated lands to pasture, perennial legumes and grasses for hay or grazing, or to woodland. In order to accomplish these land conversions it will be necessary to make some reduction in the acreage of clean tilled row crops, principally corn. Additional feed and grazing crops will permit some expansion in livestock production.

In estimating benefits and costs of open land measures, season average prices received and calendar year average prices paid (applicable to the watershed) by farmers for the crop year 1948 were used. These prices are itemized in Tables D-12 and D-13.

COSTS

Cost of production data secured, from all sources, by crops was summarized for each crop by operations. It was expected that changes would occur in the cost of normal operation of farms due to the recommended program. Certain operations, such as planting and fertilizing row crops, are not expected to change due to the recommended program, but other items, such as cost of harvest, would change if there is a change in yield. Crops affected by the recommended program with respect to yield and cost are shown by Physical Land Units and their subdivisions in Table D-14. Acreages of these crops, present and future, are shown in Table E-4, Appendix E.

The estimated cost of producing each crop per acre, present and future, is shown in Table D-15.

Unit costs of land treatment and other measures are discussed in Appendix E.

Normal Farm Operation Costs

The effect of the total watershed needs on the cost of normal farm operation by Physical Land Units and their subdivisions is shown by crops in Table D-16.

The net changes in costs of normal farm operations, based on watershed needs, summarized by Physical Land Units are as follows:

Item	Pennyroyal	Western Coal Field	Total Watershed
	Dollars	Dollars	Dollars
Net Increases in Costs	16,668,000	12,813,000	29,481,000

As will be noted in Table D-16, there are no net decreases in the cost of producing crops by Physical Land Units or their subdivisions, although there were some individual crop costs where decreases occurred.

Cost of Installing and Maintaining Open Land Treatment Measures

Total installation costs and annual maintenance costs for all open land treatment measures are shown in Table D-17. This table also shows the total number of units of each measure needed in the watershed at present and the unit cost of each. Discussion of component parts of each measure may be found in Appendix E.

The total cost of installing all open land treatment measures needed in the watershed at present is estimated to be $97,674,600. The annual cost of maintaining these measures is estimated at $12,522,100.

Cost of Installing and Maintaining Woodland Treatment Measures

Total installation costs and annual maintenance costs for all woodland treatment measures are shown in Table D-17. This table also shows the total number of units of each measure needed in the watershed at present and the unit cost of each. Component parts of each measure are discussed in Appendix E.

The total cost of installing all woodland treatment measures in the watershed at present is estimated to be $25,110,939. The annual cost of maintaining these measures is estimated at $294,705.

Cost of Tributary Channel Improvement and Stream Bank Stabilization

The cost of tributary channel improvement and stream bank stabilization was computed on a per stream mile basis. A detailed discussion of this item may be found in Appendix E.

The total cost of installing these measures and the average annual cost of both installation and maintenance chargeable to Federal, non-Federal Public, and Private sources are shown in Table D-20 by Physical Land Units. The total number of miles needing treatment and cost of treatment per mile are shown in Table D-17. This table also shows the total basic cost of installing the necessary measures and the average annual cost of maintenance for the watershed as a whole. These costs do not include a prorate share of the costs for investigation, design, planning and integrating measures, and inspection, as do the costs shown in Table D-20.

Adjustment in Cost of Watershed Needs by Measures Due to Going Programs

Estimates of annual costs of going programs were secured from the responsible agencies and multiplied by twenty to get the total effect of going programs over a twenty-year period. The effect of going programs for a twenty-year period is shown in Table D-18. This table also shows the total cost of facilitating services (technical and educational) for the same period.

By direct subtraction of the total expected physical accomplishment of going programs from total watershed needs, Appendix E, the recommended program is determined.

Cost of the Recommended Program

All direct costs of the recommended program by measures and services are shown in Table D-19. Indirect costs of the recommended program (such as increased costs of normal farm operations due to increased acreages of cover crops, increased harvest costs due to increased yields, etc.) are not included in this table. The direct costs of the recommended program are also shown broken down between Federal, non-Federal Public and Private sources.

CONSERVATION BENEFITS

Open Land Conservation Benefits

Open land conservation benefits are principally benefits to farmers due to increased farm income, but also include benefits due to reduction in maintenance costs of railroads and public roads.

Estimated changes in crop and pasture yields due to the watershed treatment program (total watershed needs) are shown in Table D-14. The estimated gross farm income per acre from each crop, from pasture, and the additional income per animal unit from livestock (using beef cows producing commercial fat calves as units of evaluation) are shown in Table D-21. The estimated acreage of crops and pastures and the estimated carrying capacity of pasture in beef cows producing commercial fat calves are shown in Table E-4, Appendix E.

The effect of the total watershed needs on gross farm income is shown in Table D-22 by Physical Land Units and their subdivisions.

The net changes in farm income, based on watershed needs, summarized by Physical Land Units are as follows:

Item	Pennyroyal	Western Coal Field	Total Watershed
	Dollars	Dollars	Dollars
Net Increases in Gross Farm Income	52,598,000	39,409,000	92,007,000

There are no net decreases in gross farm income by Physical Land Units or their subdivisions, although there were some individual crops where decreases in gross income occurred. This is shown in Table D-22.

Annual conservation benefits from reduction of public road and railroad maintenance due to erosion control are shown in Table D-23. These benefits amount to $98,500 for the Pennyroyal Physical Land Unit, $119,400 for the Western Coal Field Physical Land Unit, and $217,900 for the Green River Watershed as a whole.

Woodland Conservation Benefits

The increased protection against fire and grazing along with intensified management favoring conservative cutting and logging practices will bring about site rehabilitation. As the sites improve, the timber growth will increase and the quality of the timber products will be improved. Because of the increase in volume production and the higher price to be received for higher quality material, the conservation benefits on woodland will be high.

Present annual growth rates vary; averaging about 100 board feet per acre per year in saw-timber stands. However, because of the large area of forest land now supporting trees under saw timber size it is estimated that annual growth is less than 100 board feet per acre. Under management, the annual growth will average at least 300 board feet per acre, and in many cases exceed this figure.

In general there is some correlation between hydrologic condition and site quality, because the site quality improves with the improvement in hydrologic condition. Using this reasoning, it was estimated that the annual growth per acre in "poor" stands is about 75 board feet, and that in "good" stands is about 300 board feet. It is further estimated that the annual growth in "medium" condition stands will approximate 150 board feet per acre. These values are used for all physical land units.

Log prices vary greatly by quality. In adopting an average stumpage price, "poor" stands and "poor" sites were considered as sources of low quality logs, and "good" sites as sources of high quality logs. The average stumpage prices for logs are shown in Table D-24. The average annual income per acre for the three conditions of woodland was derived by applying these stumpage prices to the annual growth

and is indicated in Table D-24. Total income, with and without a program, for woodland is summarized in Table D-25. It is estimated that these benefits will accrue within 30 years after the program is installed.

PART III - SUMMARY AND COMPARISON OF BENEFITS AND COSTS OF THE RECOMMENDED PROGRAM

ADJUSTMENT OF COSTS FOR GOING PROGRAMS AND SUMMARY OF COSTS FOR THE RECOMMENDED PROGRAM

Adjustment of Costs for Going Programs

How adjustments were made in the costs of watershed needs for going programs by evaluable measures for flood control and waterflow retardation are discussed in Part II of this appendix. The necessary adjustments in costs are shown in Table D-18, and the costs of the remaining work to be done through the recommended program are shown in Table D-19.

However, an adjustment is also needed in changes in normal farm operation costs (due to watershed needs) for going programs. This item can best be adjusted as a total rather than by individual crops, since it must be done on a proportionate basis in the same manner that benefits are adjusted. Costs of open land treatment, channel improvement, and facilitating services of the Soil Conservation Service and the Extension Service are included in the summary of average annual costs used to derive the proportion for this purpose. The following is a summary showing how the proportions were determined:

COST OF OPEN LAND TREATMENT MEASURES, CHANNEL IMPROVEMENT, AND SOIL CONSERVATION SERVICE AND EXTENSION SERVICE SERVICES

Source of Cost	Total Cost of Installation	Average Annual Cost
	Dollars	Dollars
Recommended Program:		
Federal and Non-Federal Public 1/	36,218,600	905,465
Private 2/	23,869,200	954,768
Annual Maintenance		6,101,400
Total Average Annual Cost		7,961,633
Percent of Grand Total		(49)
Going Programs:		
Federal and Non-Federal Public 1/	30,383,000	759,575
Private 2/	23,536,300	941,452
Annual Maintenance		6,712,300
Total Average Annual Cost		8,413,327
Percent of Grand Total		(51)
Grand Total Average Annual Cost		16,374,960

1/ The average annual equivalent of all Public installation costs was determined by taking 2 1/2 percent of the total.
2/ The average annual equivalent of all private installation costs was determined by taking 4 percent of the total

The increase in costs of normal farm operation amounts to $29,481,000. Using the preceding proportions to determine the part of this increase chargeable to the recommended program, multiply $29,481,000 by 49 percent. This computation shows that $14,446,000 of the increase in normal farm operation costs is chargeable to the recommended program. The remainder is chargeable to going programs.

Summary of Costs of the Recommended Program

All costs of the recommended program, except increases in costs of normal farm operation, are shown in Table D-19 by measures and facilitating services. The following is a summary and distribution of the costs of the recommended program shown in Table D-26 by groups of measures and facilitating services and the cost due to increases in normal farm operation costs, rounded to the nearest thousand dollars: 1/

Total Installation Costs		
Federal	$56,305,000	
Non-Federal Public	1,270,000	
Private	29,026,000	
Total	$86,601,000	
Average Annual Equivalent of Installation Costs		
Federal	$ 1,407,000	
Non-Federal Public	32,000	
Private	1,161,000	
Sub-Total		$2,600,000
Annual Operation and Maintenance Costs		
Federal	$ 393,000	
Non-Federal Public	593,000	
Private	5,547,000	
Sub-Total		$6,533,000
Total Annual Direct Costs of Program Measures		$9,133,000
Increase in Annual Farm Operation Costs		$14,446,000
Total Average Annual Costs		$23,579,000

The average annual cost to channel improvement amounts to $505,000 (Table D-26) and is included in the preceding total average annual costs.

Allocation of costs of the remedial measures to Federal, non-Federal Public, and Private have been made on the basis of the following probable benefits: (1) in reduction of flood water and sediment

1/ Some individual items were forced in rounding to add to rounded totals. Additional reference will have to be made to Table D-19 to arrive at certain combinations of data by groups as shown above.

damages; (2) to soil and water conservation, mainly as a result of the farm land treatment measures; and (3) to the public in general. Table D-19 shows the distribution of installation and maintenance costs of the recommended program by measures, groups of measures, and sources (Federal, non-Federal Public, and Private). The procedure used in determining the recommended program is discussed in Appendix E.

ADJUSTMENT OF BENEFITS FOR GOING PROGRAMS AND SUMMARY OF BENEFITS FOR THE RECOMMENDED PROGRAM

Method of Adjustment of Benefits for Going Programs

All benefits to land treatment measures are divided between going programs and the recommended program. To arrive at the benefits to the recommended program, therefore, benefits to the going programs must be taken out.

The total annual benefits for land treatment measures are divided between going programs and the recommended program in proportion to the total annual costs of each. This proportion was determined from Tables D-18 and D-19 as follows:

COSTS OF FACILITATING SERVICES, CHANNEL IMPROVEMENT, AND LAND TREATMENT MEASURES

Source of Cost	Total Cost of Installation	Average Annual Cost
	Dollars	Dollars
Recommended Program:		
Federal and Non-Federal Public 1/	57,575,141	1,439,379
Private 2/	29,026,028	1,161,041
Annual Maintenance		6,532,820
Total Average Annual Cost		9,133,240
Percent of Grand Total		(52)
Going Programs:		
Federal and Non-Federal Public 1/	30,772,460	769,312
Private 2/	23,536,300	941,452
Annual Maintenance		6,731,773
Total Average Annual Cost		8,442,537
Percent of Grand Total		(48)
Grand Total Average Annual Cost		17,575,777

1/ The average annual equivalent of all Public installation costs was determined by taking 2 1/2 percent of the total.

2/ The average annual equivalent of all Private installation costs was determined by taking 4 percent of the total.

Using the preceding analysis as a basis, 52 percent of certain annual watershed benefits are assigned to the recommended program and 48 percent to the going programs. Sources and amounts of benefits (rounded to the nearest thousand dollars) affected by going programs are as follows:

Reduction in Flood Water Damages Due to Conservation Measures		
Agricultural	$1,277,000	(Table D-8)
Public Roads and Railroads	77,000	(Table D-9)
Public Water Supply	9,000	(Table D-10)
Sub-Total	$1,363,000	
Associated Benefits		
Open Land Conservation	$92,007,000	(Table D-22)
Woodland Conservation	7,477,000	(Table D-25)
Decreased Maintenance of Roads and Railroads	218,000	(Table D-23)
Sub-Total	$99,702,000	
Total		$101,065,000

Adjustment and Summary of Recommended Program Benefits

Total flood control and conservation benefits, amounting to $101,065,000, multiplied by 52 percent gives $52,554,000 as the total amount of benefits accruing to the recommended land treatment program. Add to this amount flood damage reduction benefits due to channel improvement, amounting to $801,000 (Table D-8), to arrive at total benefits of $53,355,000 assigned to the recommended program.

COMPARISON OF BENEFITS AND COSTS OF THE RECOMMENDED PROGRAM

Comparison of Benefits and Costs - Channel Improvement Only

At the 1948 cost-price level, the total average annual benefits from channel improvement and stream bank stabilization amount to $801,000 and total average annual costs amount to $505,000.

These benefits and costs are adjusted to future price levels by indexes provided by the Bureau of Agricultural Economics as follows:

	1948 Indexes	Future Indexes	Base Period
Benefit Conversion Indexes			
Farm Product Prices	199	141	(1910-14 = 100)
Items Used in Production	250	155	(1910-14 = 100)
Farm Wage Rates	442	275	(1910-14 = 100)
Cost Conversion Indexes			
Construction Costs	461	325	(1913 = 100)

Weighted conversion factors were determined from these indexes and are applied to benefits and costs for adjustment purposes to arrive at adjusted benefits and costs as follows: Benefits, $448,000; Costs, $356,000.

The adjusted channel improvement benefit-cost ratio is 1.26 to 1.

Comparison of Benefits and Costs - Recommended Program

At the 1948 cost-price level, the total average annual benefits from the recommended program (including channel improvement) amount to $53,355,000 and total average annual costs amount to $23,579,000.

These benefits and costs are adjusted to future price levels by indexes provided by the Bureau of Agricultural Economics as follows:

	1948 Indexes	Future Indexes	Base Period
Benefit Conversion Indexes			
Farm Product Prices	199	141	(1910-14 = 100)
Wholesale Lumber	312	145	(1926 = 100)
Items Used in Production	250	155	(1910-14 = 100)
Farm Wage Rates	442	275	(1910-14 = 100)
Construction Costs	461	325	(1913 = 100)
Cost Conversion Indexes			
Farm Wage Rates	442	275	(1910-14 = 100)
Items Used in Production	250	155	(1910-14 = 100)
Construction Costs	461	325	(1913 = 100)

Indexes were weighted to reflect the amounts of benefits and costs coming from each source to which the index was applicable. The adjusted benefits amount to $26,304,000, and the adjusted costs amount to $15,397,000.

The adjusted recommended program benefit-cost ratio is 1.71 to 1.

NOTES ON THE DERIVATION OF CERTAIN DATA SHOWN IN THE SURVEY REPORT

The average annual flood control benefit of $1,510,000, shown in the report is a combination of the $801,000 benefit to channel improvement only (Table D-8) and the sum of other flood-control benefits (Tables D-8, D-9, and D-10) multiplied by 52 percent (the portion of all benefits, other than that for channel improvement, assigned to the recommended program). The sum of other flood-control benefits, derived as described above and rounded to the nearest thousand dollars, is shown in Table D-27. Channel improvement benefits and associated benefits are also shown in Table D-27. These benefits were then adjusted by the use of future indexes furnished by the Bureau of Agricultural Economics, and the adjusted benefits are also shown in Table D-27. The individual weighted conversion factors are as follows: For channel improvement and other flood-control benefits, 0.559; all flood control and associated benefits, 0.493. Adjusted associated benefits were determined by

subtracting adjusted flood-control benefits from adjusted total benefits.

Federal, non-Federal Public and Private costs of the recommended program are summarized in Table D-27. These costs after adjustment by a weighted future index (derived from future indexes furnished by the Bureau of Agricultural Economics) are also shown in Table D-27. The conversion factor in making all cost adjustments shown in Table D-27 is 0.653.

To arrive at the data shown in Table 3 of the report, the following use of data in this appendix is necessary:

Reductions in flood water damages to agriculture: Multiply total other benefits (Tabld D-8) by 52 percent and add total channel improvement benefits (Table D-8).

Reductions in flood water damages to roads and railroads: Multiply total benefits to this item (Table D-11) by 52 percent.

Reductions in sediment damages: Multiply total benefits to this item (Table D-11) by 52 percent.

Woodland benefits (associated benefits): Multiply total woodland benefits (Table D-25) by 97.5 percent.

Decreased maintenance costs on public roads and railroads: Multiply total benefits to this item (Table D-23) by 52 percent.

Open land conservation benefits: Subtract all other benefits from total benefits shown in this appendix.

Table D-1

AVERAGE DAMAGEABLE VALUES PER ACRE BY MONTHS AND BY CROPS 1/
PENNYROYAL AREA TRIBUTARY SAMPLE, KENTUCKY 2/
GREEN RIVER WATERSHED

Crop	Damageable Value of Crops by Months in Dollars											
	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Corn	--	--	--	2.70	10.94	29.18	54.68	66.46	66.46	49.84	16.62	--
Small Grain	38.90	38.90	38.90	38.90	38.90	29.18	9.72	--	2.80	7.96	16.88	31.56
Burley Tobacco	--	--	4.30	16.48	36.68	233.90	541.71	512.66	170.88	--	--	--
Lespedeza (Hay)3/	--	--	--	--	--	--	25.41	19.06	6.35	--	--	--
Mixed Hay (Hay)3/	--	--	--	--	32.75	24.56	8.19	--	--	--	--	--
Pasture (Grazing)3/	--	--	--	1.05	2.10	2.10	2.10	2.10	2.10	1.05	--	--
Fescue (Seed)3/	--	--	--	--	--	46.88	15.62	--	--	--	--	--
Alfalfa (Hay)3/	--	--	--	--	21.81	10.90	10.90	10.90	--	--	--	--
Pasture and Hay (Stand)3/	6.20	6.60	7.00	7.20	7.20	6.72	6.24	5.76	5.28	5.00	5.40	5.80
Alfalfa (Stand)3/	13.80	13.80	15.21	19.81	20.70	18.98	17.25	15.52	13.80	13.80	13.80	13.80

1/ Based on 1948 prices and costs.
2/ The Barren River sample was adjusted by introduction of samples from other Pennyroyal area tributary streams.
3/ Damages to the immediate crop and damages to the stand of plants were evaluated separately for these crops, the difference in pasture and hay being only a difference in use.

Table D-2

DAMAGEABLE VALUES OF A COMPOSITE ACRE
OF OPEN FLOOD PLAIN LAND BY MONTHS AND BY CROPS 1/
PENNYROYAL AREA TRIBUTARY SAMPLE, KENTUCKY 2/
GREEN RIVER WATERSHED

Land Use	Weighted Average Damageable Values in Dollars											
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Corn	--	--	--	1.59	6.45	17.22	32.26	39.21	39.21	29.41	9.81	--
Small Grain	2.72	2.72	2.72	2.72	2.72	2.04	0.68	--	0.20	0.56	1.18	2.21
Burley Tobacco	--	--	0.04	0.16	0.37	2.34	5.42	5.13	1.71	--	--	--
Lespedeza (Hay)3/	--	--	--	--	--	--	0.51	0.38	0.13	--	--	--
Mixed Hay3/	--	--	--	--	5.90	4.42	1.47	--	--	--	--	--
Pasture (Grazing)3/	--	--	--	0.16	0.32	0.32	0.32	0.32	0.32	0.16	--	--
Fescue (Seed)3/	--	--	--	--	--	0.47	0.16	--	--	--	--	--
Alfalfa (Hay)3/	--	--	--	--	0.22	0.11	0.11	0.11	--	--	--	--
Pasture and Hay Stand 3/	2.17	2.31	2.45	2.52	2.52	2.35	2.18	2.02	1.85	1.75	1.89	2.03
Alfalfa (Stand)3/	0.14	0.14	0.15	0.20	0.21	0.19	0.17	0.16	0.14	0.14	0.14	0.14
Total Value of Composite Acre	5.03	5.17	5.36	7.35	18.71	29.46	43.28	47.33	43.56	32.02	13.02	4.38

1/ Based on 1948 prices and costs.
2/ The Barren River sample was adjusted by introduction of samples from other Pennyroyal area tributary streams.
3/ Damages to the immediate crop and damages to the stand of plants were evaluated separately for these crops, the difference in pasture and hay being only a difference in use.

Table D-3

ESTIMATED PERCENT DAMAGE BY DEPTHS OF INUNDATION
BY MONTHS FOR CORN - PENNYROYAL AREA TRIBUTARY SAMPLE, KENTUCKY
GREEN RIVER WATERSHED 1/

Depth Inundation in Feet	Percent Damage by Months											
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1	--	--	--	50	50	50	30	30	20	20	20	--
2	--	--	--	50	70	70	50	40	30	30	30	--
3	--	--	--	75	90	90	80	70	60	60	60	--
4	--	--	--	75	90	100	100	95	90	90	90	--
5	--	--	--	75	90	100	100	100	100	100	100	--
6	--	--	--	75	90	100	100	100	100	100	100	--

1/ Similar estimates were made for each crop in the flood plain.

Table D-4

ESTIMATED DAMAGE PER ACRE OF OPEN FLOOD PLAIN LAND
BY DEPTHS OF INUNDATION BY MONTHS FOR CORN -
PENNYROYAL AREA TRIBUTARY SAMPLE, KENTUCKY
GREEN RIVER WATERSHED 1/

Depth Inundation in Feet	Damage to Corn by Months in Dollars 2/											
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1	--	--	--	0.80	3.22	8.61	9.68	11.76	7.84	5.88	1.96	--
2	--	--	--	0.80	4.52	12.05	16.13	15.68	11.76	8.82	2.94	--
3	--	--	--	1.19	5.80	15.50	25.81	27.45	23.53	17.65	5.89	--
4	--	--	--	1.19	5.80	17.22	32.26	37.25	35.29	26.47	8.83	--
5	--	--	--	1.19	5.80	17.22	32.26	39.21	39.21	29.41	9.81	--
6	--	--	--	1.19	5.80	17.22	32.26	39.21	39.21	29.41	9.81	--

1/ Similar estimates were made for each crop in the flood plain.
2/ Based on 1948 prices and costs.

Table D-5

FLOOD DAMAGES TO CROPS AND PASTURE
PER ACRE OF OPEN FLOOD PLAIN LAND
BY MONTHS AND BY DEPTHS OF INUNDATION 1/
PENNYROYAL AREA SAMPLE TRIBUTARY, KENTUCKY 2/
GREEN RIVER WATERSHED

Depth Inundation in Feet	Weighted Average Damage Per Acre of Open Flood Plain Land by Months in Dollars											
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1	0.79	0.80	1.66	3.22	10.28	16.47	15.12	18.00	10.39	6.56	2.42	0.67
2	1.00	1.03	1.91	3.94	12.85	20.91	24.84	22.17	14.53	9.67	3.59	0.88
3	1.22	1.26	2.15	5.04	14.76	24.87	34.88	34.22	26.53	18.66	6.72	1.08
4	1.22	1.26	2.15	5.36	15.11	26.88	41.47	44.08	38.34	27.49	9.67	1.08
5	1.22	1.26	2.15	5.36	15.11	26.88	41.47	46.04	42.26	30.43	10.65	1.08
6	1.22	1.26	2.15	5.36	15.11	26.88	41.47	46.04	42.26	30.43	10.65	1.08

1/ Based on 1948 prices and costs.
2/ The Barren River sample was adjusted by introduction of samples from other Pennyroyal area tributary streams.

Table D-6

STAGE-AREA RELATIONSHIPS PER STREAM MILE
BY ONE-FOOT DEPTH OF INUNDATION INTERVALS
BARREN RIVER, KENTUCKY
GREEN RIVER WATERSHED

Stage in Feet	Acres Inundated by One-Foot Depth of Inundation Intervals					Total Acres Inundated
	1	2	3	4	5 and up	
14	0.0	--	--	--	--	0.0
15	7.0	0.0	--	--	--	7.0
16	16.9	7.0	0.0	--	--	23.9
17	8.3	16.9	7.0	0.0	--	32.2
18	8.7	8.3	16.9	7.0	0.0	40.9
19	4.3	8.7	8.3	16.9	7.0	45.2
20	5.2	4.3	8.7	8.3	23.9	50.4
21	5.2	5.2	4.3	8.7	32.2	55.6
22	5.8	5.2	5.2	4.3	40.9	61.4
23	3.3	5.8	5.2	5.2	45.2	64.7
24	3.1	3.3	5.8	5.2	50.4	67.8
25	3.0	3.1	3.3	5.8	55.6	70.8
26	2.9	3.0	3.1	3.3	61.4	73.7
27	2.7	2.9	3.0	3.1	64.7	76.4

Table D-7

STAGE-DAMAGE RELATIONSHIPS PER STREAM MILE 1/
PENNYROYAL AREA TRIBUTARY SAMPLE, KENTUCKY 2/
GREEN RIVER WATERSHED

Peak Stage in Feet 3/	Damage to Fixed Improvements 4/ Dollars	Damage to Crops and Pasture by Months - Dollars									
		Dec. Jan. Feb. 5/	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.
14	0	0	0	0	0	0	0	0	0	0	0
15	2	5	12	23	72	115	106	126	73	46	17
16	12	19	41	82	264	425	429	459	277	179	66
17	35	31	61	129	406	664	789	764	518	348	128
18	61	43	82	183	551	925	1,217	1,227	928	645	232
19	83	50	93	218	640	1,102	1,562	1,622	1,335	945	335
20	100	57	105	250	724	1,257	1,824	1,953	1,676	1,193	421
21	113	63	116	278	802	1,401	2,054	2,222	1,938	1,384	487
22	126	69	128	308	886	1,549	2,273	2,470	2,167	1,548	545
23	138	74	136	330	947	1,660	2,465	2,676	2,366	1,693	595
24	149	79	143	350	1,000	1,759	2,637	2,877	2,563	1,837	645
25	158	82	150	368	1,047	1,847	2,784	3,051	2,736	1,963	689
26	165	86	156	384	1,092	1,927	2,910	3,197	2,877	2,065	724
27	172	89	162	399	1,134	2,002	3,029	3,331	3,003	2,156	756

1/ Based on 1948 prices and costs.
2/ The Barren River sample was adjusted by introduction of samples from other Pennyroyal area tributary streams.
3/ Stage in feet on the Pageville gage, Barren River, Kentucky.
4/ Variation in damages to fixed improvements by months is negligible.
5/ Sufficient similarity in type and amount of damage exists in these months to permit grouping.

Table D-8

Sample	Benefits		
	Channel Improv. Benefits	Other Benefits	Total Benefits
	Dollars	Dollars	Dollars
Barren River, Ky. for the Pennyroyal Area	287,525	332,575	620,100
Pond River, Ky. for the Western Coal Field Area	513,760	944,320	1,458,080
Green River Watershed Total	801,285	1,276,895	2,078,180

1/ Includes crop and pasture dama ple tributary.
2/ Includes 160 miles of main ste ose for the
3/ Does not include 220 miles of evaluated
sample tributary. Since no ap
separately.

AGRICULTURAL DAMAGES AND BENEFITS 1/
AVERAGE ANNUAL FLOOD DAMAGES AND FLOOD REDUCTION BENEFITS
GREEN RIVER WATERSHED

Sample	Stream Miles Repre-sented	Present Damages		Future Damages				Benefits		
		Per Stream Mile	Total	With Channel Improvement		With Complete Program		Channel Improv. Benefits	Other Benefits	Total Benefits
				Per Stream Mile	Total	Per Stream Mile	Total			
	Miles	Dollars	Dollars	Dollars	Dollars	Dollars	Dollars	Dollars	Dollars	Dollars
Barren River, Ky. for the Pennyroyal Area	1,325 2/	1,050	1,391,250	833	1,103,725	582	771,150	287,525	332,575	620,100
Pond River, Ky. for the Western Coal Field Area	2,080 3/	1,633	3,396,640	1,386	2,882,880	932	1,938,560	513,760	944,320	1,458,080
Green River Watershed Total	3,405 3/		4,787,890		3,986,605		2,709,710	801,285	1,276,895	2,078,180

1/ Includes crop and pasture damage as well as damage to fixed improvements.
2/ Includes 160 miles of main stem (all main stem miles in this area - damages per stream mile being similar to the sample tributary).
3/ Does not include 2[illegible]0 miles of main stem. Damages per stream mile for this reach of Green River are several times those for the sample tributary. Since no appreciable damage reductions can be expected on this reach of the main stem, it is not evaluated seperately.

Table D-9

SUMMARY OF FLOOD DAMAGES AND BENEFITS ON PUBLIC ROADS AND RAILROADS - GREEN RIVER WATERSHED

Area	Estimated Annual Damages		Annual Benefits
	Present	Future	
	Dollars	Dollars	Dollars
Pennyroyal	184,200	147,400	36,800
Western Coal Field	202,000	161,600	40,400
Total	386,200	309,000	77,200

Physical Land Unit and Name of Town			l Cost		Annual Benefit
			am	With Program	
				Dollars	Dollars
Western Kentucky Coal Field					
Brownsville,	Ky.	Green		3,449	181
Calhoun,	Ky.	Green		10,004	526
Central City,	Ky.	Green		11,714	616
Greenville,	Ky.	Catch		6,950	366
Hartford,	Ky.	Rough		7,399	389
Livermore,	Ky.	Green		7,900	416
Morgantown,	Ky.	Green		5,609	295
Rockport,	Ky.	Green		3,648	192
Total				56,673	2,981
Pennyroyal					
Auburn,	Ky.	Spring		6,031	317
Bowling Green,	Ky.	Barren		23,647	1,245
Campbellsville,	Ky.	Pitman		9,157	482
Columbia,	Ky.	Russel		7,399	389
Elizabethtown,	Ky.	Spring		10,141	534
Franklin,	Ky.	Drake		3,565	188
Glasgow,	Ky.	Beaver		10,025	528
Greensburg,	Ky.	Green		6,810	358
Hodgenville,	Ky.	Nolin		7,296	384
Horse Cave,	Ky.	Wells		7,070	372
Liberty,	Ky.	Green		4,560	240
Munfordville,	Ky.	Green		5,510	290
Russellville,	Ky.	Mud. C		8,333	439
Tompkinsville,	Ky.	Mill C		7,669	404
Total				117,213	6,170
Grand Total				173,886	9,151

Table D-10

BENEFITS FROM REDUCED COST OF WATER TREATMENT
GREEN RIVER WATERSHED

Physical Land Unit and Name of Town		Source of Water		Plant Output 1948	Cost of Treatment	Annual Cost		Annual Benefit
		Stream	Type			Without Program	With Program	
				MG	Dollars per MG	Dollars	Dollars	Dollars
Western Kentucky Coal Field								
Brownsville,	Ky.	Green River	Run-of-stream	22	165	3,630	3,449	181
Calhoun,	Ky.	Green River	Run-of-stream	162	65	10,530	10,004	526
Central City,	Ky.	Green River	Run-of-stream	274	45	12,330	11,714	616
Greenville,	Ky.	Catchment Basin	Impounded	59	124	7,316	6,950	366
Hartford,	Ky.	Rough River	Run-of-stream	66	118	7,788	7,399	389
Livermore,	Ky.	Green River	Run-of-stream	77	108	8,316	7,900	416
Morgantown,	Ky.	Green River	Run-of-stream	41	144	5,904	5,609	295
Rockport,	Ky.	Green River	Run-of-stream	24	160	3,640	3,648	192
Total				725		59,654	56,673	2,981
Pennyroyal								
Auburn,	Ky.	Spring	Run-of-stream	46	138	6,348	6,031	317
Bowling Green,	Ky.	Barren River	Run-of-stream	889	28	24,892	23,647	1,245
Campbellsville,	Ky.	Pitman Creek	Run-of-stream	119	81	9,639	9,157	482
Columbia,	Ky.	Russell Creek	Run-of-stream	66	118	7,788	7,399	389
Elizabethtown,	Ky.	Spring	Run-of-stream	175	61	10,675	10,141	534
Franklin,	Ky.	Drakes Creek	Impounded	139	27	3,753	3,565	188
Glasgow,	Ky.	Beaver Creek	Run-of-stream	173	61	10,553	10,025	528
Greensburg,	Ky.	Green River	Run-of-stream	56	128	7,168	6,810	358
Hodgenville,	Ky.	Nolin River	Impounded	64	120	7,680	7,296	384
Horse Cave,	Ky.	Wells		61	122	7,442	7,070	372
Liberty,	Ky.	Green River	Run-of-stream	32	150	4,800	4,560	240
Munfordville,	Ky.	Green River	Run-of-stream	40	145	5,800	5,510	290
Russellville,	Ky.	Mud. Cr. Wells	Run-of-stream	86	102	8,772	8,333	439
Tompkinsville,	Ky.	Mill Creek	Impounded	69	117	8,073	7,669	404
Total				2,015		123,383	117,213	6,170
Grand Total				2,740		183,037	173,886	9,151

Table D-11

AVERAGE ANNUAL DAMAGES AND BENEFITS BY SOURCES
GREEN RIVER WATERSHED

Physical Land Unit	Agriculture	Roads and Railroads	Water Supply Silting	Total	Reduction in Damages
	Dollars	Dollars	Dollars	Dollars	Percent
		PRESENT DAMAGES			
Pennyroyal	1,391,250	184,200	123,383	1,698,833	--
Western Coal Field	3,396,640	202,000	59,654	3,658,294	--
Total	4,787,890	386,200	183,037	5,357,127	--
			BENEFITS		
Pennyroyal	620,100	36,800	6,170	663,070	39.0
Western Coal Field	1,458,080	40,400	2,981	1,501,461	41.0
Total	2,078,180	77,200	9,151	2,164,531	40.4

Table D-12

SEASON AVERAGE PRICES RECEIVED
BY GREEN RIVER WATERSHED FARMERS
1948, ALL AREAS

Commodity		Unit	Price
			Dollars
Tobacco:	Burley	Lb.	.475
	Dark Air Cured	Lb.	.265
	Dark Fired	Lb.	.298
Corn		Bu.	1.40
Small Grain:	Wheat	Bu.	2.15
	Oats	Bu.	1.00
	Rye	Bu.	2.00
	Barley	Bu.	1.50
Hay:	Clover and Timothy, all	Ton	22.00
	Lespedeza, all	Ton	20.00
	Alfalfa, all	Ton	24.00
	Soybeans and Cowpeas, all	Ton	22.00
	Small Grain, all	Ton	16.00
	Wild, all	Ton	13.00
	Other, all	Ton	21.00
	Sorghum forage, all	Ton	13.00
	All Hay	Ton	21.00
Seed:	Lespedeza	Lb.	.101
	Red Clover	Bu.	26.70
	Soybeans (oil and seed)	Bu.	2.40
	Cowpeas	Bu.	3.80
	Ky. #31 Fescue	Lb.	.50
Irish Potatoes		Bu.	1.70
Sweet Potatoes		Bu.	2.30
Beef Cattle (herd culls)		CWT	21.30
Veal Calves (commercial fat calves)		CWT	25.80

Item
Man Labor
Common
Truck and Tractor Drivers
Specialized Tobacco
Horse Labor
Tractor Cost (medium farm)
Truck and Pickup Cost
Custom Work
Harvesting
Wheat for Grain
Oats for Grain
Rye for Grain
Barley for Grain
Lespedeza for Seed
Red Clover for Seed
Soybeans for Beans
Terracing
Diversion Ditches
Farm Ponds
Hauling Tobacco to Market
Tobacco Warehouse Charge
Fertilizer
0-14-7
0-12-12
2-12-6
3-9-6
4-8-6
4-12-4
4-12-8
5-10-5
Plant Bed
Nitrate of Soda
20% Phos.
Rock Phos.
47% Phos.
Manure
Limestone (spread)
Borax

Unit	Cost
	Dollars
Lb.	.15
Yd.	.16
Lb.	.30
Lb.	.60
Load	8.00
Load	2.50
CWT	1.00
100	3.00
Each	.10
Lb.	.164
Oz.	.75
Oz.	1.50
Bu.	3.00
Bu.	2.50
Bu.	2.00
Bu.	3.00
Bu.	5.00
Lb.	.50
Lb.	.63
Lb.	.22
Lb.	.56
Lb.	.15
Lb.	.33
Lb.	.50
Lb.	.38
Lb.	.78
Lb.	2.50
Lb.	.10
Lb.	.25
Lb.	.23
Lb.	.42
Lb.	.75
Lb.	1.00
M	12.00
M	6.00
CWT	4.50
CWT	4.00
CWT	1.25
A.U.Mo.	2.00

Table D-13

APPROXIMATE AVERAGE PRICES PAID BY GREEN RIVER WATERSHED FARMERS
1948, ALL AREAS

Item	Unit	Cost
		Dollars
Man Labor		
Common	Hr.	.50
Truck and Tractor Drivers	Hr.	1.00
Specialized Tobacco	Hr.	.70
Horse Labor	Hr.	.20
Tractor Cost (medium farm)	Hr.	.65
Truck and Pickup Cost	Hr.	.65
Custom Work		
Harvesting		
Wheat for Grain	Bu.	.319
Oats for Grain	Bu.	.20
Rye for Grain	Bu.	.353
Barley for Grain	Bu.	.207
Lespedeza for Seed	Crop	(One-half)
Red Clover for Seed	Crop	(One-half)
Soybeans for Beans	Bu.	.365
Terracing	Mi.	70.00
Diversion Ditches	Mi.	100.00
Farm Ponds	Each	175.00
Hauling Tobacco to Market	CWT	.25
Tobacco Warehouse Charge	CWT	1.00
Fertilizer		
0-14-7	CWT	1.80
0-12-12	CWT	1.80
2-12-6	CWT	1.90
3-9-6	CWT	2.00
4-8-6	CWT	2.25
4-12-4	CWT	2.50
4-12-8	CWT	2.50
5-10-5	CWT	2.50
Plant Bed	CWT	2.50
Nitrate of Soda	CWT	5.00
20% Phos.	CWT	1.30
Rock Phos.	CWT	.80
47% Phos.	CWT	2.00
Manure	Ton	2.00
Limestone (spread)	Ton	3.00
Borax	CWT	5.00

Item	Unit	Cost
		Dollars
Supplies		
Twine	Lb.	.15
Tobacco Cloth	Yd.	.16
Lead Arsenate	Lb.	.30
Paris Green	Lb.	.60
Sawdust Fuel	Load	8.00
Firewood (Tob.)	Load	2.50
Coke	CWT	1.00
Tobacco Sticks	100	3.00
Bags	Each	.10
Seeds		
All Corn (average)	Lb.	.164
Dark Tobacco	Oz.	.75
Burley Tobacco	Oz.	1.50
Wheat	Bu.	3.00
Barley	Bu.	2.50
Oats	Bu.	2.00
Rye	Bu.	3.00
Soybeans	Bu.	5.00
Alfalfa	Lb.	.50
Red Clover	Lb.	.63
Sweet Clover	Lb.	.22
Alsike Clover	Lb.	.56
Lespedeza (Korean)	Lb.	.15
Sericea L.	Lb.	.33
Crimson Clover	Lb.	.50
Hairy Vetch	Lb.	.38
White D. Clover	Lb.	.78
Ladino Clover	Lb.	2.50
Timothy	Lb.	.10
Red Top	Lb.	.25
Orchard Grass	Lb.	.23
Ky. Blue Grass	Lb.	.42
Ky. #31 Fescue	Lb.	.75
Bicolor Lespedeza	Lb.	1.00
Plants		
Kudzu Plants	M	12.00
Bicolor Plants	M	6.00
Feed		
Cottonseed Meal	CWT	4.50
Other Mill Feed	CWT	4.00
Salt (livestock)	CWT	1.25
Pasture Rent	A.U.Mo.	2.00

Crop	Unit	al Field		
		Loess		
		Present	Future	Percent Increase
Burley Tobacco	Lb.	1,110	1,500	35
Dark Air Cured Tobacco	Lb.	1,100	1,480	35
Dark Fired Tobacco	Lb.	--	--	--
Corn	Bu.	40	56	40
Truck and Vegetables	Bu.	100	140	40
Soybeans for Beans	Bu.	20	30	50
Oats for Grain	Bu.	28	46	64
Barley for Grain	Bu.	25	36	44
Wheat for Grain	Bu.	17	25	47
Small Grain Hay	Ton	1.4	2.0	43
Soybean and Cowpea Hay	Ton	1.4	2.2	57
Lespedeza Hay	Ton	1.3	2.0	54
Clover and Timothy Hay	Ton	1.5	2.4	60
Other Tame and Wild Hay	Ton	1.1	2.4	118
Alfalfa-Grass Hay	Ton	2.4	3.5	46
Lespedeza Seed	Lb.	280	360	29
Pasture	A.U. Mo.	2.0	4.8	120

Note: Future increases are from s ean tilled row crops, use
of hybrids, etc., from cons

Table D-14

EFFECTS OF FARM LAND TREATMENT MEASURES ON THE YIELDS OF MAJOR CROPS PER ACRE
GREEN RIVER WATERSHED

Crop	Unit	Pennyroyal						Western Coal Field					
		Eastern			Western			Sandstone-Shale			Loess		
		Present	Future	Percent Increase	Present	Future	Percent Increase	Present	Future	Percent Increase	Present	Future	Percent Increase
Burley Tobacco	Lb.	1,110	1,500	35	1,200	1,620	35	1,080	1,460	35	1,110	1,500	35
Dark Air Cured Tobacco	Lb.	1,000	1,350	35	1,130	1,530	35	1,000	1,350	35	1,100	1,480	35
Dark Fired Tobacco	Lb.	--	--	--	1,010	1,360	35	880	1,190	35	--	--	--
Corn	Bu.	27	40	48	30	44	47	26	40	54	40	56	40
Truck and Vegetables	Bu.	80	110	38	70	110	57	70	100	43	100	140	40
Soybeans for Beans	Bu.	--	--	--	--	--	--	14	22	57	20	30	50
Oats for Grain	Bu.	23	40	74	29	46	59	27	40	48	28	46	64
Barley for Grain	Bu.	20	32	60	22	36	64	19	32	68	25	36	44
Wheat for Grain	Bu.	12	20	67	15	25	67	14	20	43	17	25	47
Small Grain Hay	Ton	0.8	1.6	100	1.0	1.8	80	0.9	1.6	78	1.4	2.0	43
Soybean and Cowpea Hay	Ton	1.2	2.0	67	1.3	2.2	69	1.4	2.2	57	1.4	2.2	57
Lespedeza Hay	Ton	0.9	1.6	78	1.1	1.8	64	1.2	1.8	50	1.3	2.0	54
Clover and Timothy Hay	Ton	1.1	1.8	64	1.2	2.0	67	1.2	2.0	67	1.5	2.4	60
Other Tame and Wild Hay	Ton	0.8	1.8	125	0.9	2.0	122	1.0	2.0	100	1.1	2.4	118
Alfalfa-Grass Hay	Ton	1.9	3.0	58	2.2	3.4	55	2.2	3.4	55	2.4	3.5	46
Lespedeza Seed	Lb.	240	360	50	240	360	50	210	340	62	280	360	29
Pasture	A.U. Mo.	2.0	5.0	110	2.5	5.5	76	1.5	3.6	140	2.0	4.8	120

Note: Future increases are from soil conserving practices only — excludes such practices as direct fertilization of clean tilled row crops, use of hybrids, etc., from consideration.

Table D-15

COST OF PRODUCING CROPS 1/, PRESENT AND FUTURE
1948 AVERAGE PRICES
GREEN RIVER WATERSHED

Enterprise	Unit	Pennyroyal				Western Coal Field			
		Eastern		Western		Sandstone-Shale		Loess	
		Present	Future	Present	Future	Present	Future	Present	Future
		$	$	$	$	$	$	$	$
Burley Tobacco	Ac.	331	395	342	412	326	390	317	382
Dark Air Cured Tobacco	Ac.	220	254	231	269	227	263	224	260
Dark Fired Tobacco	Ac.	-	-	259	308	246	289	-	-
Corn	Ac.	28	30	27	29	28	30	26	28
Truck and Vegetables	Ac.	114	126	106	122	106	118	129	145
Orchard, etc. 2/	Ac.	44	44	52	52	54	54	70	70
Soybeans for Beans	Ac.	-	-	-	-	25	27	25	28
Oats, Grain	Ac.	21	26	21	26	21	24	18	22
Barley, Grain	Ac.	22	26	22	26	22	26	21	24
Wheat, Grain	Ac.	18	22	19	23	19	22	19	22
Small Grain Hay	Ac.	21	29	23	30	22	29	25	30
Soybean and Cowpea Hay	Ac.	14	22	14	22	15	22	14	20
Lespedeza Hay	Ac.	12	19	14	21	15	21	15	22
Clover and Timothy Hay	Ac.	14	21	15	23	15	23	17	25
Other Annual and Biennial Hay	Ac.	11	21	12	23	13	23	14	25
Alfalfa-Grass Hay	Ac.	25	31	26	33	26	34	26	33
Lespedeza Seed	Ac.	12	18	12	18	11	17	14	18
Cover Crops Turned	Ac.	12	12	12	12	12	12	12	12
Pasture 1/	Ac.	4	10	5	11	3	7	4	10

1/ Excludes land rent except in case of pasture where total rental is used as basis of charge to livestock.
2/ No change anticipated - cost and income held equal.

ESTIMA

Sources of Cost		Green River Watershed	
	Future	Present	Future
	Dollars	Dollars	Dollars
Burley Tobacco	9,833,676	20,433,856	24,487,506
Dark Air Cured Tobacco	,192,580	3,247,946	3,770,390
Dark Fired Tobacco	--	601,701	707,648
Soybeans for Beans	562,492	616,875	686,314
Truck and Vegetables	1 734,425	5,281,041	5,904,653
Orchards, Vineyards, etc.	207,200	1,107,940	1,107,940
Corn	6,582,376	21,367,293	14,725,706
Oats, Grain	49,236	664,791	1,189,988
Barley, Grain	57,648	459,539	744,360
Wheat and Rye, Grain	498,388	2,596,410	4,274,084
Small Grain Hay	--	58,473	--
Soybean and Cowpea Hay	299,720	847,763	1,072,030
Lespedeza Hay	320,364	2,414,827	4,474,450
Clover and Timothy Hay	233,250	983,295	2,034,628
Other Tame and Wild Hay	342,250	987,330	2,319,089
Lespedeza and Red Clover Seed	108,306	231,886	490,170
Deep Rooted Perennials	842,688	1,355,630	6,574,340
Cover Crops	,043,420	1,044,876	7,070,160
Rotation and Permanent Pasture	1,888,690	5,896,925	18,045,455
Total Cost	23,796,709	70,198,397	99,678,911

Table D-16

ESTIMATED TOTAL COST OF PRODUCING CROPS BY PHYSICAL LAND UNITS AND THEIR SUBDIVISIONS
1948 AVERAGE PRICES
GREEN RIVER WATERSHED

Sourcee of Cost	Pennyroyal				Western Coal Field				Green River Watershed	
	Eastern		Western		Sandstone-Shale		Loess			
	Preeent	Future	Present	Future	Present	Future	Present	Future	Present	Future
	Dollare	Dollare	Dollars	Dollars	Dollars	Dollare	Dollars	Dollars	Dollare	Dollars
Burley Tobacco	9,326,918	11,130,310	5,889,240	7,094,640	2,866,192	3,428,880	2,351,506	2,833,676	20,433,856	24,487,506
Dark Air Cured Tobacco	278,520	321,564	755,370	879,630	325,064	376,616	1,888,992	2,192,580	3,247,946	3,770,390
Dark Fired Tobacco	--	--	53,613	63,756	548,088	643,892	--	--	601,701	707,648
Soybeans for Beane	--	--	--	--	114,650	123,822	502,225	562,492	616,875	686,314
Truck and Vegetablee	1,826,394	2,018,646	879,694	1,012,478	1,921,568	2,139,104	653,385	734,425	5,281,041	5,904,653
Orcharde, Vineyards, etc.	275,308	275,308	195,052	195,052	430,380	430,380	207,200	207,200	1,107,940	1,107,940
Corn	6,539,036	4,699,500	4,296,213	3,049,930	7,187,040	3,393,900	3,345,004	3,582,376	21,367,293	14,725,706
Oats, Grain	257,859	578,500	2[illegible],264	291,148	138,768	271,104	45,900	49,236	664,791	1,189,988
Barley, Grain	127,050	273,988	188,562	237,328	86,702	175,396	57,225	57,648	459,539	744,360
Wheat and Rye, Grain	641,880	1,425,468	794,485	1,021,384	672,638	1,328,844	487,407	498,388	2,596,410	4,274,084
Small Grain Hay	17,598	--	9,315	--	12,210	--	19,350	--	58,473	--
Soybean and Cowpea Hay	66,262	--	45,122	--	526,575	772,310	209,804	299,720	847,763	1,072,030
Lespedeza Hay	819,840	1,457,224	256,942	855,015	1,039,545	1,841,847	298,500	320,364	2,414,827	4,474,450
Clover and Timothy Hay	354,466	595,833	176,085	746,304	236,130	459,241	216,614	233,250	983,295	2,034,628
Other Tame and Wild Hay	221,694	476,112	121,140	643,471	383,214	857,256	261,282	342,250	987,330	2,319,089
Leepedeza and Red Clover Seed	19,344	32,652	71,868	298,926	26,070	50,286	114,604	108,306	231,886	490,170
Deep Rooted Perennials	338,250	1,665,723	828,100	1,464,045	107,874	2,601,884	81,406	842,688	1,355,630	6,574,340
Cover Crope	269,856	2,001,984	211,260	1,221,564	350,148	1,803,192	213,612	2,043,420	1,044,876	7,070,160
Rotation and Permanent Pasture	1,735,016	5,684,100	1,998,115	5,063,729	1,469,238	4,408,936	694,556	2,838,690	5,896,925	18,045,455
Total Cost	23,115,291	32,636,912	16,992,440	24,138,400	18,442,094	25,106,890	11,648,572	17,796,709	70,198,397	99,678,911

Table D-17

Measure 1/	Annual Maintenance	
	Unit Cost	Total Cost
	Dollars	Dollars
LAND TREATMENT		
Open Land		
1. Sub-Watershed Waterways	48	168,000
2. Farm Waterways	6	82,800
3. Terracing	4	464,400
4. Diversion	8	56,000
5. Gully Stabilization	12	52,800
6. Road and Railroad Bank S	41	271,800
7. Perennial Vegetation	13	1,765,400
8. Pasture Development	5	9,360,000
9. Farm Ponds	7	239,400
10. Wildlife Area Developmen	3	61,500
Sub-Total		12,522,100
Woodland		
11. Fire Control	--	136,897
12. Forest Planting	--	128
13. Acquisition	--	--
14. Management of Flood Cont	--	157,680
Sub-Total		294,705
TRIBUTARY CHANNEL IMPROVEMENT STREAM BANK STABILIZATION	108	291,600
Total		13,108,405

1/ See Tables D-18 and D-19 f

Table [illegible]-17

BASIC INSTALLATION AND MAINTENANCE COSTS OF WATERSHED NEEDS
GREEN RIVER WATERSHED, 1948 AVERAGE PRICES

Measure 1/	Unit	Watershed Needs	Cost of Installation		Annual Maintenance	
			Unit	Total	Unit Cost	Total Cost
			Dollars	Dollars	Dollars	Dollars
LAND TREATMENT						
Open Land						
1. Sub-Watershed Waterways	Mile	3,500	1,200	4,200,000	48	168,000
2. Farm Waterways	Acre	13,800	50	690,000	6	82,800
3. Terracing	Mile	116,100	75	8,707,500	4	464,400
4. Diversion	Mile	7,000	150	1,050,000	8	56,000
5. Gully Stabilization	Mile	4,400	200	880,000	12	52,800
6. Road and Railroad Bank Stabilization	Mile	6,630	150	994,500	41	271,800
7. Perennial Vegetation	Acre	135,800	42	5,703,600	13	1,765,400
8. Pasture Development	Acre	1,872,000	36	67,392,000	5	9,360,000
9. Farm Ponds	Number	34,200	220	7,524,000	7	239,400
10. Wildlife Area Development	Acre	20,500	26	533,000	3	61,500
Sub-Total				97,674,600		12,522,100
Woodland						
11. Fire Control	Acre	2,151,465	--	2,737,940	--	136,897
12. Forest Planting	Acre	727,973	--	12,649,399	--	128
13. Acquisition	Acre	438,000	--	6,570,000	--	--
14. Management of Flood Control Lands	Acre	438,000	--	3,153,600	--	157,680
Sub-Total				25,110,939		294,705
TRIBUTARY CHANNEL IMPROVEMENT AND STREAM BANK STABILIZATION	Mile	2,700	2,700	7,290,000	108	291,600
Total				130,075,539		13,108,405

1/ See Tables D-18 and D-19 for Facilitating Services.

Table D-18

	Annual ACP	Total ACP
	Dollars	Dollars
LAND TREATMENT		
Open Land		
1. Sub-Watershe	--	--
2. Farm Waterwa	519	10,380
3. Terracing	7,216	144,320
4. Diversions	2,032	40,640
5. Gully Stabil	34	680
6. Road and Rai	--	--
7. Perennial Ve	769	15,380
8. Pasture Deve	1,187,861	23,757,220
9. Farm Ponds	35,919	718,380
10. Wildlife Are	--	--
Sub-Total	1,234,350 2/	24,687,000 2/
Woodland		
11. Fire Control	--	--
12. Forest Plant	--	--
13. Acquisition	--	--
14. Management o	--	--
Sub-Tota	--	--
FACILITATING SERV		
15. Technical Se	--	--
16. Educational	--	--
Sub-Total		
Total	-- 2/	-- 2/

1/ Includes Priva
2/ The ACP payment Total ACP = Annual ACP X 20.
3/ Acreage accompl
4/ Soil Conservati
5/ Includes $880,(

Table D-18

ANTICIPATED ACCOMPLISHMENTS AND COSTS OF "GOING" PROGRAMS
OF LAND TREATMENT FOR 20-YEAR PERIOD
GREEN RIVER WATERSHED

Measures	Unit	Amount	Total Costs of Installation 1/	Annual Maintenance Cost	Annual ACP	Total ACP
			Dollars	Dollars	Dollars	Dollars
LAND TREATMENT						
Open Land						
1. Sub-Watershed Waterways	Mile	--	--	--	--	--
2. Farm Waterways	Acre	1,500	75,000	9,000	519	10,380
3. Terracing	Mile	5,500	412,500	2[illegible],000	7,216	144,320
4. Diversions	Mile	1,600	240,000	12,800	2,032	40,640
5. Gully Stabilization	Mile	--	--	--	34	680
6. Road and Railroad Bank Stabilization	Mile	--	--	--	--	--
7. Perennial Vegetation	Acre	48,700	2,045,400	633,100	769	15,380
8. Pasture Development	Acre	1,187,000	42,732,000	5,935,000	1,187,861	23,757,220
9. Farm Ponds	Number	11,600	2,552,000	81,200	35,919	718,380
10. Wildlife Area Development	Acre	6,400	166,400	19,200	--	--
Sub-Total			48,223,300	6,712,300	1,234,350 2/	24,687,000 2/
Woodland						
11. Fire Control	Acre	-- 3/	326,880	16,344	--	--
12. Forest Planting	Acre	-- 3/	2,560	128	--	--
13. Acquisition	Acre	--	--	--	--	--
14. Management of Flood Control Lands	Acre	--	--	--	--	--
Sub-Total			329,440	16,472	--	--
FACILITATING SERVICES						
15. Technical Services 4/	--	--	4,372,020	3,001	--	--
16. Educational Assistance 5/	--	--	1,384,000	--	--	--
Sub-Total			5,756,020	3,001		
Total			54,308,760	6,731,773	-- 2/	-- 2/

1/ Includes Private costs as well as ACP payments.
2/ The ACP payments are a part of the total cost of installation and are included in the total cost column. Total ACP = Annual ACP X 20.
3/ Acreage accomplished by "going" program is insignificant for these woodland measures.
4/ Soil Conservation Service, $4,312,000; and Forest Service, $60,020 and $3,001.
5/ Includes $880,000 Federal and $504,000 State and local Public funds.

Table D-19

Items	Annual Maintenance		
	Federal	Non-Federal Public	Non-Federal Private
	Dollars	Dollars	Dollars
LAND TREATMENT			
Open Land 2/			
1. Sub-Watershed Waterways	--	--	168,000
2. Farm Waterways	--	--	73,800
3. Terracing	--	--	442,400
4. Diversions	--	--	43,200
5. Gully Stabilization	--	--	52,800
6. Road and Railroad Bank Stabiliza	--	262,400	9,400
7. Perennial Vegetation	--	--	1,132,300
8. Pasture Development	--	--	3,425,000
9. Farm Ponds	--	--	158,200
10. Wildlife Area Development	--	--	42,300
Sub-Total	--	262,400	5,547,400
Woodland			
11. Fire Control	82,217	38,336	--
12. Forest Planting	--	--	--
13. Land Acquisition	--	--	--
14. Management of Flood Control Land	157,680	--	--
Sub-Total	239,897	38,336	--
CHANNEL IMPROVEMENT AND STREAM BANK STABILIZATION 2/	--	291,600	--
FACILITATING SERVICES			
15. Technical Services 3/	138,187	--	--
16. Educational Assistance	--	--	--
17. Testing Effectiveness of Program	15,000	--	--
Sub-Total	153,187	--	--
Total	393,084	592,336	5,547,400

1/ This table does not include amount
2/ These costs include $1,187,000 for on and supervision prorated to the cost of the various measures.
3/ Soil Conservation Service, $1,644,
4/ Installation: Open land, $140,000

Table D-19

INSTALLATION, MAINTENANCE, AND OTHER COSTS BY GROUPS OF MEASURES
OF RECOMMENDED PROGRAM AND ALLOCATION OF COSTS 1/
GREEN RIVER WATERSHED, 1948 AVERAGE PRICES

Items	Unit	Total Amount	Installation: Total Costs 2/	Installation: Federal	Installation: Non-Federal Public	Installation: Non-Federal Private	Annual Maintenance: Total	Annual Maintenance: Federal	Annual Maintenance: Non-Federal Public	Annual Maintenance: Non-Federal Private
			Dollars	Dollars	Dollars	Dollars	Dollars	Dollars	Dollars	Dollars
LAND TREATMENT										
Open Land 2/										
1. Sub-Watershed Waterways	Mile	3,500	4,296,700	3,666,700	--	630,000	168,000	--	--	168,000
2. Farm Waterways	Acre	12,300	629,400	321,900	--	307,500	73,800	--	--	73,800
3. Terracing	Mile	110,600	8,485,800	4,338,300	--	4,147,500	442,400	--	--	442,400
4. Diversions	Mile	5,400	828,300	423,300	--	405,000	43,200	--	--	43,200
5. Gully Stabilization	Mile	4,400	900,900	460,900	--	440,000	52,800	--	--	52,800
6. Road and Railroad Bank Stabilization	Mile	6,630	1,018,000	520,700	480,000	17,300	271,800	--	262,400	9,400
7. Perennial Vegetation	Acre	87,100	3,741,900	1,912,800	--	1,829,100	1,132,300	--	--	1,132,300
8. Pasture Development	Acre	685,000	25,228,600	12,898,600	--	12,330,000	3,425,000	--	--	3,425,000
9. Farm Ponds	Number	22,600	5,087,000	2,601,000	--	2,486,000	158,200	--	--	158,200
10. Wildlife Area Development	Acre	14,100	374,400	191,100	--	183,300	42,300	--	--	42,300
Sub-Total			50,591,000	27,335,300	480,000	22,775,700	5,809,800	--	262,400	5,547,400
Woodland										
11. Fire Control	Acre	2,151,465	2,411,060	1,644,330	766,730	--	120,553	82,217	38,336	--
12. Forest Planting	Acre	727,973	12,646,839	7,467,222	22,789	5,156,828	--	--	--	--
13. Land Acquisition	Acre	438,000	6,570,000	6,570,000	--	--	--	--	--	--
14. Management of Flood Control Lands	Acre	438,000	3,153,600	3,153,600	--	--	157,680	157,680	--	--
Sub-Total			24,781,499	18,835,152	789,519	5,156,828	278,233	239,897	38,336	--
CHANNEL IMPROVEMENT AND STREAM BANK STABILIZATION 2/	Mile	2,700	7,457,300	6,363,800	--	1,093,500	291,600	--	291,600	--
FACILITATING SERVICES										
15. Technical Services 3/	--	--	3,025,870	3,025,870	--	--	138,187	138,187	--	--
16. Educational Assistance	--	--	395,500	395,500	--	--	--	--	--	--
17. Testing Effectiveness of Program 4/	--	--	350,000	350,000	--	--	15,000	15,000	--	--
Sub-Total			3,771,370	3,771,370	--	--	153,187	153,187	--	--
Total			86,601,169	56,305,622	1,269,519	29,026,028	6,532,820	393,084	592,336	5,547,400

1/ This table does not include amounts or costs of "going" programs.
2/ These costs include $1,137,000 for investigations, design, planning and integrating measures and $120,000 for inspection and supervision prorated to the cost of the various measures.
3/ Soil Conservation Service, $1,644,000 and Forest Service, $1,381,870.
4/ Installation: Open land, $140,000 and Woodland, $210,000. Maintenance: Open land, $6,000 and Woodland, $9,000.

Table D-20

CHANNEL IMPROVEMENT AND STREAM BANK STABILIZATION
SUMMARY OF AMOUNTS, COSTS AND ALLOCATION OF COSTS
GREEN RIVER WATERSHED

Area	Amount	Installation Costs			
		Total	Federal	Non-Federal	
				Public	Private
	Miles	Dollars	Dollars	Dollars	Dollars
		TOTAL INSTALLATION COSTS			
Basic Costs of Recommended Program					
Pennyroyal	1,100	2,970,000	2,524,500		445,500
Western Coal Field	1,600	4,320,000	3,672,000		648,000
Total	2,700	7,290,000	6,196,500		1,093,500
Total Costs Including Certain Prorated Federal Expenses 1/					
Pennyroyal	1,100	3,038,200	2,592,700		445,500
Western Coal Field	1,600	4,419,100	3,771,100		648,000
Total	2,700	7,457,300	6,363,800		1,093,500
		AVERAGE ANNUAL COSTS			
Annual Equivalent of Installation					
Pennyroyal		82,600	64,800		17,800
Western Coal Field		120,200	94,300		25,900
Sub-Total		202,800	159,100		43,700
Annual Operation and Maintenance					
Pennyroyal		118,800		118,800	
Western Coal Field		172,800		172,800	
Sub-Total		291,600		291,600	
Total Annual Costs					
Pennyroyal		201,400	64,800	118,800	17,800
Western Coal Field		293,000	94,300	172,800	25,900
Facilitating Services		10,300	10,300	--	--
Total		504,700	169,400	291,600	43,700

1/ These costs include $167,300 for investigations, design, planning and integrating measures and for inspection and supervision.

Table D-21

GROSS INCOME FROM CROPS AND LIVESTOCK, PRESENT AND FUTURE
1948 AVERAGE PRICES
GREEN RIVER WATERSHED

Enterprise	Unit	Pennyroyal				Western Coal Field			
		Eastern		Western		Sandstone-Shale		Loess	
		Present	Future	Present	Future	Present	Future	Present	Future
		$	$	$	$	$	$	$	$
Burley Tobacco	Ac.	527	712	570	770	513	694	527	712
Dark Air Cured Tobacco	Ac.	265	358	299	405	265	358	292	392
Dark Fired Tobacco	Ac.	-	-	301	405	262	355	-	-
Corn	Ac.	38	56	42	62	36	56	56	78
Truck and Vegetables	Ac.	184	253	161	253	161	230	230	322
Orchards, etc.	Ac.	44	44	52	52	54	54	70	70
Soybeans, Beans	Ac.	-	-	-	-	34	53	48	72
Oats, Grain	Ac.	23	40	29	46	27	40	28	46
Barley, Grain	Ac.	30	48	33	54	28	48	38	54
Wheat, Grain	Ac.	26	43	32	54	30	43	37	54
Small Grain Hay	Ac.	13	26	16	29	14	26	22	32
Soybean and Cowpea Hay	Ac.	26	44	29	48	31	48	31	48
Lespedeza Hay	Ac.	18	32	22	36	24	36	26	40
Clover and Timothy Hay	Ac.	24	40	26	44	26	44	33	53
Other Annual and Biennial Hay	Ac.	17	38	19	42	21	42	23	50
Alfalfa-Grass Hay	Ac.	46	72	53	82	53	82	58	84
Lespedeza Seed	Ac.	24	36	24	36	21	34	28	36
Pasture 1/	Ac.	4	10	5	11	3	7	4	10
Beef 2/	Brood Cow	56	68	56	68	50	68	58	68

1/ Pasture rental is used as both cost and income from pasture. Additional income from pasture, grain and hay is included as beef produced.

2/ This item is evaluated as beef cows producing commercial fat calves and includes only the increase in farm income resulting from this use of pasture, grain, and hay. Costs were deducted from gross farm income and are, therefore, not shown in the cost table.

ESTIMATED TOTALIR SUBDIVISIONS

Source of Income	...pess	Green River Watershed	
	Future	Present	Future
	Dollars	Dollars	Dollars
Burley Tobacco	5,281,616	33,084,788	44,705,400
Dark Air Cured Tobacco	3,305,736	4,155,136	5,595,970
Dark Fired Tobacco	--	646,043	874,775
Soybeans for Beans	1,446,408	1,120,196	1,689,466
Truck and Vegetables	1,630,930	8,367,561	11,953,330
Orchards, Vineyards, etc.	207,200	1,107,940	1,107,940
Corn	9,979,476	32,002,508	31,607,696
Oats, Grain	102,948	839,169	1,959,896
Barley, Grain	129,708	669,991	1,452,252
Wheat and Rye, Grain	1,223,316	4,276,461	9,004,776
Small Grain Hay	--	42,172	--
Soybean and Cowpea Hay	719,328	1,769,346	2,404,368
Lespedeza Hay	582,480	3,814,198	7,659,944
Clover and Timothy Hay	494,490	1,742,648	3,935,670
Other Tame and Wild Hay	684,500	1,582,710	4,286,494
Lespedeza and Red Clover Seed	216,612	461,402	980,340
Deep Rooted Perennials	2,145,024	2,711,925	15,926,862
Rotation and Permanent Pasture	2,888,690	5,896,925	18,045,455
Beef Cows Producing Commercial Fat Calves	9,432,620	28,481,490	61,588,688
Total Income	40,471,082	132,772,609	224,779,322

Table D-22

ESTIMATED TOTAL GROSS FARM INCOME FROM CROPS, PASTURE AND LIVESTOCK BY PHYSICAL LAND UNITS AND THEIR SUBDIVISIONS
1948 AVERAGE PRICES
GREEN RIVER WATERSHED

Source of Income	Pennyroyal				Western Coal Field				Green River Watershed	
	Eastern		Western		Sandstone-Shale		Loess			
	Present	Future	Present	Future	Present	Future	Present	Future	Present	Future
	Dollars	Dollars	Dollars	Dollars	Dollars	Dollars	Dollars	Dollars	Dollars	Dollars
Burley [illegible]	14,849,806	20,062,736	9,815,400	13,259,400	4,510,296	6,101,648	3,909,286	5,281,616	33,084,788	44,705,400
Dark Air Cured Tobacco	335,490	453,228	977,730	1,324,350	379,480	512,656	2,462,436	3,305,736	4,155,136	5,595,970
Dark Fired Tobacco	--	--	62,307	83,835	583,736	790,940	--	--	646,043	874,775
Soybeans for Beans	--	--	--	--	155,924	243,058	964,272	1,446,408	1,120,196	1,689,466
Truck and Vegetables	2,947,864	4,053,313	1,336,139	2,099,647	2,918,608	4,169,440	1,164,950	1,630,930	8,367,561	11,953,330
Orchards, Vineyards, etc.	275,308	275,308	195,052	195,052	430,380	430,380	207,200	207,200	1,107,940	1,107,940
Corn	8,874,406	8,772,400	6,682,998	6,520,540	9,240,480	6,335,280	7,204,624	9,979,476	32,002,508	31,607,696
Oats, Grain	282,417	890,000	306,936	515,108	178,416	451,840	71,400	102,948	839,169	1,959,896
Barley, Grain	173,250	505,824	282,843	492,912	110,348	323,808	103,550	129,708	669,991	1,452,252
Wheat and Rye, Grain	927,160	2,786,142	1,338,080	2,398,032	1,062,060	2,597,286	949,161	1,223,316	4,276,461	9,004,776
Small Grain Hay	10,894	--	6,480	--	7,770	--	17,028	--	42,172	--
Soybean and Cowpea Hay	123,058	--	93,467	--	1,088,255	1,685,040	464,566	719,328	1,769,346	2,404,368
Lespedeza Hay	1,229,760	2,454,272	403,766	1,465,740	1,663,272	3,157,452	517,400	582,480	3,814,198	7,659,944
Clover and Timothy Hay	607,656	1,134,920	305,214	1,427,712	409,292	878,548	420,486	494,490	1,742,648	3,935,670
Other Tame and Wild Hay	342,618	861,536	191,805	1,175,034	619,038	1,565,424	429,249	684,500	1,582,710	4,286,494
Lespedeza and Red Clover Seed	38,688	65,304	143,736	597,852	49,770	100,572	229,208	216,612	461,402	980,340
Deep Rooted Perennials	622,380	3,868,776	1,688,050	3,637,930	219,897	6,275,132	181,598	2,145,024	2,711,925	15,926,862
Rotation and Permanent Pasture	1,735,016	5,684,100	1,998,115	5,063,729	1,469,238	4,408,936	694,556	2,888,690	5,896,925	18,045,455
Beef Cows Producing Commercial Fat Calves	8,410,080	19,456,432	8,572,200	17,202,776	7,201,700	15,496,860	4,297,510	9,432,620	28,481,490	61,588,688
Total Income	41,785,851	71,324,291	34,400,318	57,469,649	32,297,960	55,524,300	24,286,480	40,471,082	132,772,609	224,779,322

Table D-23

ANNUAL BENEFITS FROM REDUCTION OF
PUBLIC ROAD AND RAILROAD MAINTENANCE
GREEN RIVER WATERSHED

Area	Annual Cost of Road Maintenance Due to Erosion		Benefits
	Without Program	With Program	
	Dollars	Dollars	Dollars
Pennyroyal	197,100	98,600	98,500
Western Coal Field	238,700	119,300	119,400
Total	435,800	217,900	217,900

Table D-24

AVERAGE STUMPAGE PRICES, ANNUAL GROWTH PER ACRE, AND ANNUAL INCOME PER ACRE FROM WOODLAND BY HYDROLOGIC CONDITION CLASSES GREEN RIVER WATERSHED

Hydrologic Condition Class	Average Stumpage Price	Average Annual Growth	Average Annual Income
	Dollars/M	Board Feet/Acre	Dollars/Acre
Good	16.00	300	4.80
Medium	12.00	150	1.80
Poor	8.00	75	.60

Table D-25

ESTIMATED ANNUAL INCOME FROM WOODLAND
WITH AND WITHOUT A WATERSHED TREATMENT PROGRAM
GREEN RIVER WATERSHED

Physical Land Unit	Annual Income		Benefits
	With Program	Without Program	
	Dollars	Dollars	Dollars
Western Coal Field	5,264,700	744,536	4,520,164
Pennyroyal	3,561,363	604,044	2,957,319
Total	8,826,063	1,348,580	7,477,483

Table D-26

Groups o[illegible]	[illegible]l
	Private
	Dollars
LAND TREATMENT	
Open Land	22,776,000
Woodland	5,157,000
Sub-Total	27,933,000
CHANNEL IMPROVEMEN[illegible]	
STABILIZATION	1,093,000
FACILITATING SERVI[illegible]	--
Total Installat[illegible]	29,026,000
LAND TREATMENT	
Installation 3/	1,117,000
Operation and Ma[illegible]	5,547,000
Facilitating Ser[illegible]	--
Sub-Total	6,664,000
CHANNEL IMPROVEMEN[illegible]	
STABILIZATION	
Installation 3/	44,000
Operation and Ma[illegible]	--
Facilitating Ser[illegible]	--
Sub-Total	44,000
Total Average An[illegible]	6,708,000

1/ These costs are [illegible] addition forced numbers) after [illegible]

2/ Facilitating se[illegible]n proportion to the total monet[illegible]

3/ Installation an[illegible]plying total Federal and non[illegible]

Table D-26

SUMMARY AND DISTRIBUTION OF COSTS OF THE RECOMMENDED PROGRAM 1/
1948 AVERAGE PRICES
GREEN RIVER WATERSHED

Groups of Measures	Total	Federal	Non-Federal	
			Public	Private
	Dollars	Dollars	Dollars	Dollars
	TOTAL INSTALLATION COSTS			
LAND TREATMENT				
Open Land	50,591,000	27,335,000	480,000	22,776,000
Woodland	24,782,000	18,835,000	790,000	5,157,000
Sub-Total	75,373,000	46,170,000	1,270,000	27,933,000
CHANNEL IMPROVEMENT AND STREAM BANK STABILIZATION	7,457,000	6,364,000	--	1,093,000
FACILITATING SERVICES 2/	3,771,000	3,771,000	--	--
Total Installation Costs	86,601,000	56,305,000	1,270,000	29,026,000
	AVERAGE ANNUAL COSTS			
LAND TREATMENT				
Installation 3/	2,303,000	1,154,000	32,000	1,117,000
Operation and Maintenance	6,088,000	240,000	301,000	5,547,000
Facilitating Services 2/ & 3/	237,000	237,000	--	--
Sub-Total	8,628,000	1,631,000	333,000	6,664,000
CHANNEL IMPROVEMENT AND STREAM BANK STABILIZATION				
Installation 3/	203,000	159,000	--	44,000
Operation and Maintenance	292,000	--	292,000	--
Facilitating Services 2/ & 3/	10,000	10,000	--	--
Sub-Total	505,000	169,000	292,000	44,000
Total Average Annual Costs	9,133,000	1,800,000	625,000	6,708,000

1/ These costs are based on Table D-19 and rounded to the nearest thousand dollars (except where cross addition forced numbers) after computations were made.

2/ Facilitating services are prorated to annual land treatment costs and to channel improvement costs in proportion to the total monetary weight of each.

3/ Installation and facilitating services costs were converted to an average annual equivalent by multiplying total Federal and non-Federal public costs by 2 1/2 percent and private costs by 4 percent.

Table D-27

COMPARISON OF UNADJUSTED (1948 PRICES AND COSTS) AND ADJUSTED AVERAGE ANNUAL BENEFITS AND COSTS OF THE RECOMMENDED PROGRAM

	Unadjusted	Adjusted 1/
	Dollars	Dollars
BENEFITS:		
Channel Improvement	801,000	448,000
Other Flood Control	709,000	396,000
Associated	51,845,000	25,460,000
Total	53,355,000	26,304,000
COSTS:		
Federal	1,800,000	1,175,000
Non-Federal		
Public	625,000	408,000
Private	21,154,000	13,814,000
Total	23,579,000	15,397,000

1/ Adjusted by use of future indexes furnished by the Bureau of Agricultural Economics.

APPENDIX E

PLAN OF IMPROVEMENT

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PLAN OF IMPROVEMENT

INTRODUCTION

The recommended watershed treatment program for the Green River drainage basin in Kentucky and Tennessee has been developed with the primary objective of alleviating flood water and sediment damages.

The total area of the watershed is approximately 5,934,720 acres, of which 5,693,219 acres are in Kentucky and 241,501 acres are in Tennessee.

Of the total area, approximately 80 percent, or 4,764,654 acres, is land in farms, and 20 percent, or 1,170,066 acres, is land not in farms. All of the non-farm lands are included in non-farm woodland with the exception of 215,430 acres of miscellaneous lands which are in urban areas, roads, streams, etc.

Special consideration has been given to those measures which will result in maximum flood control and water conservation benefits. Because of the inter-relation between such measures and sound land use practices, it is essential that a complete system of soil and water conservation be developed as an integral part of the recommended program if maximum benefits are to be realized.

For evaluation purposes, all measures included in the recommended program have been grouped as follows:

Group 1 - All land treatment measures and other measures closely associated with land treatment.
Group 2 - Measures not included in Group 1, but supplemental to land treatment measures.

Measures included in Group 1 were further subdivided into two groups:

A. Land treatment measures that will be installed under the "going" programs during installation period.

B. All remaining land treatment measures and additional measures essential to the application and proper functioning of the land treatment measures.

Procedure Used in Developing Recommended Program

An analysis of physical land conditions showing capability classes and present land use was used as basic data to indicate the present condition of the watershed (Table E-1). Recommendations for land treatment, based on the experience of Soil Conservation Service and other local agricultural workers and that of local soil conservation district supervisors, were developed to show the needs for treatment within the watershed. Accomplishments on farms through June 1949 were considered in estimating needs in kinds and amounts of measures.

More than 90 percent of the entire watershed area is in active soil conservation districts. Conferences were held with supervisors and technicians representing eleven agencies in all the physical land unit areas within the watershed under consideration. At each of these conferences, charts were presented which indicated present land uses as revealed by the 1945 census, also tabulations were shown indicating the acreage of land capability classes in each land use, as obtained from sample soil conservation surveys. Using these data as a basis, also taking into consideration local agricultural trends including availability of farm labor and present economic conditions, the supervisors recommended land use changes, as well as the conservation practices needed, in order to apply a complete watershed program in their respective districts.

The present and proposed uses, together with net changes by Physical Land Units are shown in Table E-2.

These proposed land use changes are based on recommendations of the governing bodies of local soil conservation districts but adjusted to and summarized by major Physical Land Units, (Figure E-1). It will be noted that the significant changes are: Increased pasture, 451,000 acres; increased perennial hay, 147,000 acres; increased woodland, 166,000 acres; increased wildlife, 20,000 acres; decreased rotated cropland, 161,000 acres; and the application of beneficial measures to 623,000 acres of idle land.

In order to arrive at the annual rate of accomplishment of "going" programs for the needed measures, records and reports of the various agencies concerned were analyzed to determine this rate.

The fiscal year 1949 was used as a basis for estimating the annual rate of accomplishment on farms cooperating with soil conservation districts. The calendar year 1947 was considered most representative as to accomplishment rates for the Production and Marketing Administration. An estimate of watershed needs by measures, the reported accomplishment of "going" programs, and the recommended program are shown in Table E-3.

GROUP 1 - LAND TREATMENT MEASURES

Open Land

The proposed measures and practices for both flood control and conservation of watershed lands will conserve soil and water, accelerate infiltration, reduce runoff and increase soil fertility. The proposed measures and practices for open land are: (1) Sub-watershed waterways, (2) Farm waterways, (3) Terracing and field diversions, (4) Gully stabilization, (5) Road and railroad bank stabilization, (6) Perennial vegetation, (7) Pasture development, (8) Farm ponds, (9) Wildlife area development, and other farm and water conservation practices and measures, including technical and educational assistance.

There are approximately 374,000 acres of crop and idle lands in Capability Classes VI and VII (Table E-1). Since these generally severely

eroded areas are the principal sources of silt and accelerated runoff which increase flood hazards and damages, it is desirable that they be planted to deep rooted perennials, permanent pasture, and/or trees. It is proposed that approximately 15 percent of this area be planted to deep rooted perennials, 40 percent to permanent pasture, and the remaining 45 percent to trees. These conversions will give more protection to the watershed lands and a larger permanent return of hay, pasture and woodland products as well as increased food and cover for wildlife.

The remedial program imposes no major change in the acreage of cash crops. The principal cash crops will continue to be tobacco and wheat. Corn and soybean acreages will continue to be about the same in the Loess area of the Western Coal Field. It will be noted that the largest single item of net change (Table E-2) is the elimination of 623,400 acres of idle land, thus bringing into safe and beneficial use this large area of unprofitable and unprotected land. The proposed increase of close growing crop acres and the decrease of row crop acres (Table E-4) is in keeping with current trends toward increased production of livestock which necessitates substantial increased pasture and hay crops. The increased pasture and hay crop acreage also means an increased safety margin in using the land within its capabilities. Row crop acres, in approved crop rotations, will be sufficient for economic needs on the better classes of land requiring less complex conservation measures.

These necessary conservation measures and land use changes serve a dual purpose in the recommended program: First, they reduce runoff and sedimentation from critical silt-source areas, which are distinct public benefits; secondly, they conserve soil and water and improve land with concomitant increased revenue to land owners, thereby resulting in private benefits.

Sub-Watershed Waterways

The waterways on individual farms discharge storm runoff into secondary channels which in turn flow through other farms and finally discharge into the tributary streams. This concentrated volume of uncontrolled runoff produces excessive scour in the secondary channels which will seriously damage the bottom lands by deposition of harmful sediment. It is therefore important that adequate water disposal systems be planned, established, and maintained as group enterprises.

When the water disposal system of two or more individual farms discharges into a common outlet, it is necessary to provide adequate channel capacity, as well as to apply measures which will prevent both excessive scour and the formation of gullies. In some cases, this difficulty can be alleviated only by providing channel outlets entirely across the flood plains to the tributary stream outlets.

In some cases, the topography will permit the establishment of perennial vegetative outlets for group water disposal systems which will serve as meadows for the production of hay. Where secondary channels exist, brushing operations and some grading may be necessary to prevent meandering and the concentration of flows. In some instances, structures may be necessary where large quantities of runoff or eroding soils exist. Approximately 3500 miles of sub-watershed waterways will require treatment.

Farm Waterways

Farm waterways will consist of both natural and artificial water courses to provide safe disposal of excess water from farms. Farm waterways will, in most cases, be vegetated and will include such measures as broad meadow strips, constructed channels, and vegetated terrace outlets. The natural topography of adjacent farms will determine the planning and installation of water disposal systems in order that the water disposal systems of all farms involved may operate as a unit. Waterways will usually extend from the top of terraced slopes to suitable outlets. In some cases it will be necessary for waterways to cross flood plain land to reach suitable outlets. The proper disposal of excess water from farm land into adequate outlets will reduce sediment damage to lower lying lands and minimize consequent reduction in yields to these lands. Supporting structures will be installed to implement vegetative control where necessary. It is estimated that 12,300 acres of farm waterways will be needed.

Terracing and Field Diversions

Terraces will be installed to manage the runoff from sloping lands, principally those in cultivation, and to reduce soil erosion and sediment damages. Field diversions will generally be installed on slopes, and at toe-slopes, too steep for terraces, but where orderly discharge of surface runoff is necessary for the protection of lands lying immediately below them. Approximately 110,600 miles of terracing and 5,400 miles of diversion are recommended.

Gully Stabilization and Sediment Control

Gullies are one of the principal sources of sediment. The effectiveness of the recommended program in reducing sedimentation damage depends, to a large extent, on the control of gully erosion.

In the watershed under consideration it is estimated that there are a total of approximately 4,400 miles of major gullies which will require treatment. This is exclusive of those occurring in woods and occasional gullies that will be stabilized under normal conservation farm operations.

Gully treatment will consist of vegetative stabilization and supporting structural measures as required. Mulching, small check dams, and other structural measures will facilitate the establishment of kudzu, sericea, grass, shrubs, and other perennials. Temporary dikes and diversion ditches will be constructed so as to intercept and divert drainage from overlying areas into stabilized waterways where practicable. Fence construction and plantings will be used as necessary for protection of such areas from grazing.

Road Bank Stabilization

A reconnaissance survey was conducted to determine the present conditions of the road system within the Green River Watershed with respect to the types and amounts of erosion control measures necessary to stabilize the cut and fill slopes.

The road system lends itself to classification by three types: Principal Highways (hard surface); Improved Roads (soil type and surface treated); and Unimproved Roads.

The principal highways will require the greatest amounts of stabilization measures. This is a reflection of the limitations with respect to alignment and grade which produce larger cut and fill areas per mile of highway.

The improved roads will require smaller amounts of stabilization measures than principal highways but larger amounts than the unimproved roads. Existing gullies adjacent to roads will also require vegetative stabilization measures.

Recommended treatment measures for 6,400 miles of road bank erosion control consist of stabilizing structures and vegetative plantings as may be required on all highways and public roads within the watershed.

The measures on roads will generally consist of seedbed preparation, including fertilization, seeding or planting of vegetative cover, as well as mulching steep slopes. Suitable vegetation will be planted along outfall ditches and other silt source areas. Structures will be used where high runoff velocities or erosion hazards make vegetative measures inadequate.

Vine type perennial vegetation is generally recommended for the deep and steeply cut slopes and ditch sections. Perennials and reseeding

annual types of vegetation are recommended for the flatter slopes where conditions are favorable for their growth.

The stabilization of road cut and fill slopes and drainage ways will effect a major reduction in the volume of sand and silt transported from these areas. This will reduce the volume of such material deposited in road ditches and drainage ways, or on lower lying agricultural lands and inevitably in the streams. The cost of maintenance of road rights-of-way and damages to adjacent farm lands will be reduced to a minimum.

Railroad Bank Stabilization

Erosion control along railroad rights-of-way differs from that of highways in that the fill-slopes along railways are usually protected with adequate vegetation in order to protect the roadbed. However, the steep, unprotected cut-slopes contribute silt, and it is these areas on which the major portion of 230 miles of vegetative planting is recommended.

Perennial Vegetation

Combinations of perennial grasses and legumes in the proposed program serve a dual purpose: First, they afford immediate protection to the land from serious erosion and runoff problems; secondly, they provide hay and grazing for livestock. Such conservation practices as land preparation, fertilizing, liming, seeding, and others will be necessary on about 87,100 acres to attain desirable hydrologic conditions on these lands.

Pasture Development

About 526,000 acres of old pasture lands will need additional treatment such as fertilizing, liming, seeding, and other renovating measures in order to improve the hydrologic condition to a desirable level.

It is proposed that an additional 159,000 acres of crop and idle land be established in perennial grasses and legumes for permanent pasture. These acres will require such treatment as land preparation, liming, fertilizing, seeding, fencing, and other measures necessary to establish and maintain good cover conditions.

These land use changes and renovating measures serve a dual purpose in the recommended program: First, they provide heavy duty vegetation for the poorer classes of land which would otherwise require more complex and expensive measures in order to materially reduce runoff and sediment damages; second, with proper maintenance and grazing practices they provide additional pasture for an expected increase in livestock production.

Farm Ponds

In order to effect the necessary land use conversions resulting in increased pasture areas, approximately 22,600 farm ponds will be

constructed. The conversion of severely eroding cropland and idle land to pasture will generally be contingent on adequate stock water development for those areas.

Wildlife Area Development

Small irregular and inaccessible areas, as well as narrow strips of land along field borders, often left idle are sources of serious erosion and present annoying runoff problems. It is proposed that this condition be corrected by planting approximately 14,100 acres of such areas to adapted plants that will control erosion and produce food and cover for wildlife. Fences will be constructed or planted where necessary to furnish protection from grazing.

Woodland Measures:

Adequate Fire Control

Adequate protection of woodland from fire is necessary if the woodlands are to operate efficiently as hydrologic units. A standard restricting the woodland area burned annually to 1/10 of 1 percent of the area protected should be followed in watershed management for flood control purposes. However, this standard must be considered as an average figure over a period of years. Some years the area burned will be less, and in other years it will be more than the allowable area burned.

This standard of fire control is now maintained in the 45,000 acres of woodland lying within the Mammoth Cave National Park. Here the annual burn has been restricted to 1/100th of 1 percent of the area protected. Elsewhere, the area burned annually exceeds the 1/10th of 1 percent standard.

Organized fire control on state and private lands is limited to approximately 285,600 acres in the Western Coal Field Physical Land Unit. In 1948,1/ the area burned in this protected zone amounted to 1.87 percent of the protected area. The State Forester estimates that about 3 percent of the woodland in the unprotected area is burned every year.

Fire control measures must be installed in the unprotected area and intensified in the protected area if the program objectives are to be attained (Table E-5). These measures generally will include (1) installation of detection and suppression systems in the zone now unprotected, (2) intensification of detection and suppression systems in the present protected zone, and (3) additional educational measures to overcome public apathy throughout the watershed.

1/ Last year for which summarized records are available.

Protection Against Livestock

All of the watershed woodland (about 2,151,465 acres) will be protected by confining livestock to enclosed pasture as planned under the pasture phase of the remedial program.

Forest Planting

Erosion is rapid and soil stabilization is difficult on many critical cleared and woodland areas which are contributing huge amounts of sediment and flood runoff. Because the invasion by natural vegetation is slow, these lands must be artificially revegetated to stabilize the soil, prevent sedimentation, and retard runoff. The revegetation of such areas in forest land, whether wooded or cleared, will be done by planting forest trees.

To be effective in flood control the stocking of forest stands should be at least 1,000 trees per acre, well distributed over the area. The number of trees planted per acre will vary according to the stocking. Where denudation is complete, full planting of 1,000 trees per acre will be necessary. Other areas will require less than 1,000 planted trees to bring the stand up to full stocking. Partial planting on such areas will require an average of about 500 trees per acre.

Considerable difficulty is expected in obtaining satisfactory survival of planted trees on certain sites in the watershed. To meet this situation, it will be necessary to conduct investigations regarding species, size, and age, of planting stock most likely to succeed on the problem areas.

Approximately 727,973 acres should be revegetated by planting forest trees (Table E-6).

Technical Assistance to the Woodland Owner

The management of woodland for flood control will require additional practices or modifications of present practices applied and considered adequate for timber production purposes. To maintain favorable hydrologic conditions, great care must be taken to prevent rapid drying of the forest soil and to prevent type conversions from the better hardwoods to pines and less desirable hardwoods. This will require good silvicultural practice involving the judicious selection of management species and the use of light cuts and short cutting cycles. To prevent woodland from becoming sediment source areas, the forest soil must be protected from erosion. This will necessitate vigilance during harvesting operations to check skid trail and logging road erosion when it first becomes evident. These aims will be accomplished by providing technical assistance to the woodland owner.

The technical assistance provided under flood control will include management activities and such additional activities as may be necessary to facilitate management. Included will be such activities as:

1. Advice on all phases of woodland management with particular emphasis on soil stabilization and water control.

2. Assistance in locating buyers for the stumpage and timber products produced to insure proper management practices.

3. Advice in framing contracts for the sale of stumpage or timber products to insure the maintenance of good cover conditions.

4. Advice and assistance in marking timber for harvesting to produce and maintain good soil and cover conditions.

5. Advice as to the location of skid trails and logging roads to minimize soil losses and accelerated runoff.

6. Inspection, after logging in company with the woodland owner, to indicate to the owner what should have been done in specific instances.

As provisions are made for fire control as a program measure, these technical assistants should not be employed on fire suppression except under abnormal circumstances. Neither should they be employed as administrators of public land. For the most part, their activities should be confined to assisting the private woodland owner and those public agencies whose woodland holdings are too small for the efficient use of a full-time technician.

The area for which technical assistance will be furnished amounts to approximately 1,664,005 acres. It is estimated that 26 technicians will be necessary to assist the woodland owners in the Green River Watershed. The area of woodland to be serviced by technical assistants is as follows:

Physical Land Unit and State	Area to be Serviced
	Acres
Western Coal Field	
Kentucky	805,766
Pennyroyal	
Kentucky	766,187
Tennessee	92,052
Total Pennyroyal	858,239
Watershed	1,664,005

Public Acquisition of Forest Lands

A considerable area of private land in the Western Coal Field, abandoned or undergoing abandonment, is unsuited for agricultural purposes. Many of these lands have been so abused that they are in an advanced stage of erosion and are contributing large quantities of sediment and flood runoff. Other lands, although still fairly well vegetated, are nevertheless potential flood and sediment source threats because the owners cannot or will not give them the protection and the type and intensity of management essential to maintain soil stability and favorable runoff conditions.

This land must come into the flood control program to make the program effective, because with continued abuse and neglect, erosion and flood runoff will be accelerated. In many cases, because the owners will not participate in the program, the only recourse is for the public to acquire the land for flood control purposes. 1/ Therefore, 438,000 acres have been designated for Federal purchase in that portion of the watershed delineated in Figure E-3.

It is proposed that these critical, abused lands be placed under Federal ownership and so managed as to provide full watershed benefits. This will be the responsibility of the Federal land managing agency.

Other Conservation Practices and Measures

Additional soil and water conservation practices and measures will be applied as needed for obtaining a proper combination with the mutually supporting measures listed above and to complete a basic system of soil and water conservation and proper land use in accordance with the needs and capabilities of the land of the watershed. This will include other farm and woodland practices and measures that may be required to make more effective or facilitate the installation of the above measures. This will produce the most practical, workable combination of measures that will be most efficient in providing runoff and waterflow retardation and soil erosion prevention.

GROUP 2 MEASURES - SUPPLEMENT TO LAND TREATMENT

Tributary Channel Improvement and Stream Bank Stabilization

A survey was made on the sample tributaries of the Green River Watershed to ascertain the present condition of the tributary stream channels and the kinds and amounts of channel improvement measures which would be effective in alleviating flood damages.

1/ There are some farms in the "acquisition zone" which, with their woodland, will come within the program. Therefore, the land of any owners who desire to participate in the program should not be considered for acquisition.

The following sample streams are representative tributaries within the Physical Land Units: The Barren River above the stream gage near Pageville, Kentucky, to represent streams in the Pennyroyal area; and Pond River above the stream gage near White Plains, Kentucky, to represent streams in the Western Coal Field Area (Figure E-1).

Present Condition of Sample Tributary Streams

In general the gradients and channel cross sections of the sample stream in the Pennyroyal area are stable. Only very minor aggradation has taken place. The banks and side slopes of channel are covered with a heavy growth of briars, bushes, vines, and trees.

In the Western Coal Field area, the upper reaches of tributary streams are stable. The low gradient of the lower reaches of the streams together with the backwater effect of the Green River has brought about some aggradation of stream channels.

Drainage districts have been organized; however, no major dredging operations have been done in the past ten years. Only limited maintenance has been practiced on the work completed. Channels are covered with a dense growth of trees and bushes and some channel fill has taken place.

Recommended Channel Improvement

Channel improvement is recommended for tributary streams in the Pennyroyal and Western Coal Fields. This improvement consists of snagging, removal of logs and debris, and brushing, as well as the removal of trees from stream channels and banks. Logs and brush will be removed from the flood way to avoid future clogging of the channels.

Intermittent dredging and realignment is recommended for about 20 percent of the total length of the tributary streams.

In addition to dredging, realigning, clearing and snagging operations, it will be necessary to establish vegetation to stabilize the side slopes of the channels.

Scope of Channel Improvement Operations

The type and amount of channel improvement found beneficial and necessary for the sample tributary streams were expanded to include all the tributary streams in the Green River Watershed.

Channel improvement consisting of brushing and snagging operations, as well as the establishment and maintenance of vegetation, will be required on approximately 80 percent, or 2,700 miles, of the tributary streams. Channel dredging and realignment will be necessary on 20 percent, or 700 miles, of the above tributary streams.

These improvement operations will be beneficial in that stream discharge will be materially increased, flood damages will be immediately reduced, and future maintenance costs will be minimized.

It is contemplated that the landowners will be responsible for the removal of logs and other debris from the flood way during the initial clearing operations. Also, they will be responsible for the planting of vegetation and subsequent brushing, as well as annual maintenance.

UNIT COST AND ALLOCATIONS OF COST

Open Land

Unit costs for the installation and annual maintenance of the remedial measures were computed from available data and information. Contacts were made with Federal and State Experiment Stations, Soil Conservation Service technicians, contractors, and related people within or near the watershed. Unit costs are estimates as to types and quantities of labor and materials needed and are based on 1948 average prices in Kentucky.

Estimated initial cost per unit for installation and maintenance of recommended measures are as follows:

	Measure	Unit	Installation	Annual Maintenance
			Dollars	Dollars
	Group 1			
1.	Sub-watershed Waterways	Mi.	1,200.00	48.00
2.	Farm Waterways	Ac.	50.00	6.00
3.	Terracing	Mi.	75.00	4.00
4.	Field Diversions	Mi.	150.00	8.00
5.	Gully Stabilization	Mi.	200.00	12.00
6.	Road and Railroad Bank Stabilization	Mi.	150.00	41.00
7.	Perennial Vegetation	Ac.	42.00	13.00
8.	Pasture Development	Ac.	36.00	5.00
9.	Farm Ponds	No.	220.00	7.00
10.	Wildlife Area Development	Ac.	26.00	3.00
	Group 2			
1.	Tributary Channel Improvement and Stream Bank Stabilization	Mi.	2,700.00	108.00

Installation and annual maintenance costs are divided between Federal, non-Federal Public, and Private sources according to the expected contributions and benefits (Table D-15, Appendix D). It is recommended that the installation costs of all open land treatment measures except sub-watershed waterways be paid 50 percent from Federal funds and 50 percent from non-Federal Public or Private funds; that State and County Highway Departments bear 50 percent of installation on road bank stabilization costs; and that farmers, railroad companies, and other flood plain property owners provide the 50 percent Private share of installation costs on the other open land measures. It is expected that non-Federal Public (for road work) and Private sources will bear the annual maintenance costs except as otherwise noted.

Sub-watershed waterway and channel improvement (including stream bank stabilization) installation costs are recommended to be paid 85 percent from Federal and 15 percent from Private funds. Annual maintenance of channel improvement work is to be handled by legally organized state or local units. All of the annual maintenance work on sub-watershed waterways will be borne by private landowners.

All of the above percentages are of the initial costs. Certain other Federal expenses of a general nature, such as investigations, designs, inspection, supervision and planning, and integrating measures, have been prorated and added to the initial Federal installation costs.

Woodland

Organized protection of the watershed woodland against fire is so important that it is considered to be a public responsibility. Therefore, the additional fire control on state and private woodland should be a joint responsibility of the State and Federal Governments, while that on the National Forest lands should be the responsibility of the Federal Government.

It is recommended that Federal flood control funds finance the entire cost of protection required for the federally acquired land. It is further recommended that Federal flood control funds finance the intensification of organized fire control on state and private woodland to the extent of one-half of the difference between the amount required for adequate fire control and that now being spent for protecting those lands.

Three zones of relative fire hazard are recognized (Figure E-2). The estimated costs of protection, as obtained from the state foresters of Tennessee and Kentucky, U. S. Forest Service, and U. S. Park Service, vary according to zone as well as by ownership. Estimated unit costs for fire control[1] are as follows:

1/ Unit costs per acre to restrict area burned to 1/10th of 1 percent of the area protected.

Hazard Zone	Ownership and State			
	National Forest	National Park	State and Private	
			Kentucky	Tennessee
	Dollars	Dollars	Dollars	Dollars
High	.10	--	.07	.11
Medium	--	.237	--	.05
Low	--	--	.03	.03

Maintenance costs of fire control, during the installation period of 20 years, are approximately $0.06 per acre.

The unit costs for planting are listed below. The price for stock was obtained from the State Foresters of Kentucky and Tennessee; the cost of planting the trees was based on discussions with the above State Foresters, and the cost for site examination was estimated on the basis of the distribution of the plantable area in the watershed.

It is proposed that (1) the Federal Government bear the cost of the preliminary examination on all public and private lands; (2) all public agencies finance the purchase of planting stock and the planting operation on lands under their jurisdiction; and (3) the Federal Government and private owners share equally the cost of the planting stock and the planting operation on private lands.

Estimated unit costs per acre for forest planting are as follows: For full planting (1,000 trees/acre) and partial planting (500 trees/acre) $21.00 and $13.50, respectively. These costs include: Planting stock, $8.00 and $4.00; labor, $12.50 and $9.00; and preliminary examination, $0.50, respectively.

The, per acre, unit costs of technical assistance for the watershed management of woodland for flood control will be approximately $0.90 during the 20-year installation. Annual, per acre, maintenance thereafter will amount to about $0.09. This maintenance is proposed as a Federal cost. However, state and local governments should be encouraged to contribute to the cost, and if they do, the Federal contribution will be reduced accordingly.

The publicly acquired lands for flood control purposes will require management and in many instances special handling. Based on similar costs for the Cumberland National Forest, it is estimated that this will amount to $0.36 per acre or $157,680 annually for the entire 438,000 acres to be purchased. As these lands will be under Federal ownership, the cost of managing them should be borne by the Federal Government.

The estimated per acre cost of purchasing this land is as follows:

Cost of land	$12.50
Cost of acquiring land	2.50
Total cost of acquisition, per acre	$15.00

Testing Effectiveness of the Program

Information is needed to serve as a guide for directing the remedial program after the measures have been installed. Information is also needed for evaluating the cumulative effectiveness of the various measures after they have been applied. It is proposed, therefore, that a number of stream-gaging and sediment-measuring stations be established to measure quantitatively the effects of the planned watershed improvement program on runoff retardation and sediment reduction. These stations should be established on selected subwatersheds, especially in portions of the watershed where runoff conditions are particularly critical.

This test will be conducted by the Federal Government at an estimated cost of $50,000 for installation plus $15,000 annually for maintenance. During the 20-year establishment period, the total cost, installation and maintenance, will approximate $350,000.

ACTIVITIES RELATED TO FLOOD CONTROL

The Corps of Engineers

The Corps of Engineers completed a report on the Green, Barren, and Rough Rivers in 1932 (House Document No. 81, 73rd Congress). Reservoirs have been authorized at Mining City, Rough River, Nolin River, No. 2 Green, and No. 2 Barren. Contingent on the construction of Rough River reservoir, 64 miles of stream channel work was authorized for Barnett Creek, which is a tributary of Rough River.

Navigation is maintained with locks and dams on about 228 miles of the Green River and its tributaries.

Woodland Management

The Federal and State Governments are cooperating in organized fire control under the Clarke-McNary Act, and in farm forestry under the Morris-Doxey Act. These governments are also engaged in activities concerning the control of forest insects and diseases.

Educational Activities and Incentives

Federal and State Experiment Stations within or near the watershed supply valuable information and data on measures and practices related to flood control and conservation of watershed lands. The agricultural colleges, vocational agricultural schools, and the

U. S. Department of Agriculture Cooperative Extension Service have obtained local recognition of many farm problems and have also rendered valuable assistance by educating the public to appreciate the need for conservation measures. The Production and Marketing Administration makes conservation payments and materials available to individual farmers for carrying out soil and water conservation practices.

Soil Conservation Districts

Kentucky and Tennessee have enacted legislation whereby more than 90 percent of the total watershed lands are in active soil conservation districts. The U. S. Department of Agriculture cooperates with these districts to the extent of supplying technical assistance through the Soil Conservation Service. The soil and water conservation program as promoted by these districts is an integral part of the recommended program.

State Departments of Conservation

The Kentucky Department of Conservation through its Division of Soil and Water Resources is authorized to acquire and to make available to soil conservation districts heavy or specialized machinery or equipment which an individual district cannot itself economically obtain. The Department, through its Flood Control and Water Usage Board, also makes studies and recommendations as necessary to establish a state-wide program of flood control. The Board reviews, for the state, all survey reports, engineering reports, and other reports concerning projects within the state related to flood control and the usage of water resources.

The Tennessee Department of Conservation encourages conservation of land, water, forest, and wildlife. It is especially active in the improvement and protection of wildlife resources and in the management of State Parks.

State Highway Departments

The State Highway Departments of Kentucky and Tennessee are aiding in the prevention of sedimentation in many places by sloping and stabilizing cut and fill slopes. It is anticipated that no difficulty will be experienced in obtaining their full assistance in carrying out the proposed program.

Private Interests

District supervisors, technicians, and other agricultural and conservation leaders present at various meetings and contacts within the watershed agree that the recommended program is feasible. They are of the opinion that a high percent of the landowners would cooperate if the proposed flood control remedial program is authorized.

Railroad companies have already treated much of their rights-of-way for erosion control, and it is believed that they will cooperate in completing the program.

ESTIMATED COST OF "GOING" PROGRAMS

The total cost of technical assistance required for the "going" program is charged to Federal funds and is shown in Table D-18.

Soil Conservation Service in Cooperation with Soil Conservation Districts

The fiscal year 1949 was used as a base for estimating the annual cost (including administrative and facilitating services) of the Soil Conservation Service assistance to districts in the Green River Watershed. The cost was arrived at by determining the percent of watershed farm land in each district and by proportioning total personnel and facilitating cost on this basis. Personnel cost represents salaries paid to local technicians. Facilitating cost represents transportation, office rent, supplies, administrative and technical supervision and related assistance. The estimated annual cost is $215,600.

Federal Activities on Forest Lands

The Federal Government is now engaged in activities on forest lands which contribute to flood control objectives. Approximately $19,473 of Federal funds were spent for this purpose in 1949. These expenditures were distributed as follows:

U. S. Forest Service	
Fire control on State and Private lands	$6,116
Forest plantings on Private lands	121
Technical assistance to woodland owners	3,001
	$9,238
National Park Service	
Fire control on National Park lands	$10,228
Production and Marketing Administration	
Forest planting on private lands	7
Total Annual Cost	$19,473

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UNIVERSITY OF KENTUCKY
College of Agriculture and Home Economics
Agricultural Extension Division

Lexington 29, Ky.
April 28, 1950

Mr. H. G. Edwards
Chief, Regional Water
Conservation Division
Soil Conservation Service
Spartanburg, South Carolina

Dear Mr. Edwards:

Your request came to us recently through Mr. Gayle for a breakdown of the cost of maintaining our present Extension program in the 31 counties in the Green River Watershed, and an estimate of the ratio of Federal funds to those that originate within the State insofar as the 31 counties are concerned.

He also stated that you would need an estimate of the percentage of the time of those agents that is devoted to work having a direct bearing upon soil conservation and retardation of water runoff.

Total cost of agents in 31 counties	$227,694
Paid from funds of Federal origin	143,903
Paid from funds raised within the State	83,791
Percentage of time of the 31 agents devoted to work directed at soil conservation and retardation of water runoff	29.3

We have your further request for an estimate of the cost of Extension Education for the accelerated program under flood control authority.

Your discussion on April 27 of the proposed work in the Green River watershed places the project on a basis quite different from the one to which my letters of April 11 and 18 referred; however, we shall be pleased to cooperate as fully as possible in the work under the revised plan.

From the discussions we now understand that the survey phases of the work have been conducted by the SCS with no formal help from the College, but the College will be expected to give the best counsel possible to the SCS while the survey report is in preparation.

When the report has been completed and a remedial program in aid of flood control has been authorized, and when funds have been provided for the actual

Page 2
Mr. H. G. Edwards

work, the Extension Service will be pleased to take an active part insofar as funds are provided.

It is our understanding that you estimate that for each 100,000 acres involved, the equivalent of one man-year of time from Extension personnel would be required. According to the figures that you gave us there are 5,693,219 acres in the area under consideration. This, according to your estimate would require the equivalent of 57 man-years. Assuming that installation of the work will extend over a 20-year period it would seem that a total of $370,500 will be required, or $18,525 per year on the average. The amount of work and the funds required might easily vary from year to year.

This estimate is quite different from the other because it is now proposed that we confine ourselves to the educational campaign, reaching small segments of the total area at any given time.

We trust that this information is the material required.

Yours very truly,

Thomas Cooper
Dean and Director

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COOPERATIVE EXTENSION WORK
AGRICULTURE AND HOME ECONOMICS
STATE OF TENNESSEE

Knoxville 7, Tennessee
P. O. Box 1071

May 2, 1950

Mr. H. G. Edwards, Chief
Water Conservation Division
Soil Conservation Service
Spartanburg, South Carolina

Dear Mr. Edwards:

In reply to a request by Mr. Oren for a breakdown of the cost of the maintenance of our present Extension program in the three counties in the Green River Watershed and an estimate of the ratio of Federal funds to those that originate within the State insofar as the 3 counties are concerned.

We estimate that current expenditures for Extension educational efforts toward the adoption of soil conservation and retardation of water runoff in the three counties in Tennessee amounted to approximately $2500 per year of which approximately $1800 from Federal funds and $700 from State and County funds. These estimated expenditures include part of the salaries of county extension agents in the three Tennessee counties, namely, Sumner, Macon and Clay, specialists, secretaries, travel and supplies. They were arrived at by allocating the estimated fraction of each of the above costs which is for extension efforts to encourage the adoption of the above named practices and allocating the result on the basis of the fraction of the area of each county which is in the Green River Watershed.

In answer to the second request of Mr. Oren we have estimated that approximately $25,000 would be required for an accelerated Extension program necessary to achieve adoption of the practices which would control soil conservation and retardation of water runoff in addition to the continuation of such expenditures at the present rate as set out in the paragraph above.

When the report has been completed and a remedial program in aid of flood control has been authorized and when funds have been provided for the actual work the Extension Service in Tennessee will be pleased to take an active part insofar as funds are provided.

Yours very truly,

Robert W. Moore
Vice Director

The following copies of letters from State offices of Production and Marketing Administration in Tennessee and Kentucky and record of phone call to Kentucky State Office give the basic data for estimating the Federal cost and accomplishments for this part of "going" programs.

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UNITED STATES DEPARTMENT OF AGRICULTURE
PRODUCTION AND MARKETING ADMINISTRATION
129 Eighth Avenue, North
Nashville 3, Tennessee
April 7, 1950

To : Mr. H. G. Edwards, Chief of Water Conservation Division - SCS

From : Chairman, Tennessee State PMA Committee /s/ Carl Fry

Subject: Information Requested from PMA For Revising Flood Control Survey Report on Green River Watershed

We are submitting data as shown below as requested by Mr. Loy E. Rast and Mr. E. A. Oren of the Soil Conservation Service.

INDEX OF INFORMATION REQUESTED

1. Tributary channel improvement and streambank stabilization
2. Gully stabilization
3. Farm drainage
   a. Tile drainage
   b. Open ditches
4. Erosion control along roads and railroads
5. Diversion ditches
6. Terracing
7. Farm ponds
8. Pasture improvement
   a. Old pasture
   b. New pasture
9. Perennial vegetation (such as alfalfa-grass)
10. Sub-watershed waterways
11. Wildlife area improvement
12. Water disposal areas
13. Tree planting

COUNTY	ITEM	EXTENT OF PRACTICES CARRIED OUT	TOTAL EST. COST TO GOV. INCLUDING ADM. EXPENSES
Clay	1	None	None
	2	None	None
	3	(a) None	None
		(b) 855 cu. yds.	$73.00
	4	None	None
	5	None	None
	6	4,500 ft.	$50.00
	7	200 cu. yds.	$22.00
	8	(a) 75 acres	$600.00 **
		(b) 3 acres	$47.00 **
	9	6 acres	$65.00 **
	10	None	None
	11	None	None
	12	1 acre	$18.00 **

** Includes lime, phosphate and potash used in establishing this practice.

2-Mr. H. G. Edwards-4/7/50

COUNTY	ITEM	EXTENT OF PRACTICES CARRIED OUT	TOTAL EST. COST TO GOV. INCLUDING ADM. EXPENSES
Macon	1	None	None
	2	None	None
	3	None	None
	4	None	None
	5	None	None
	6	38,000 ft.	$412.00
	7	2,911 cu. yds.	$32.00
	8	(a) 750 acres	$6,000.00 **
		(b) 50 acres	$812.00 **
	9	35 acres	$389.00 **
	10	None	None
	11	None	None
	12	None	None
	13	1 acre	$8.00

** Includes lime, phosphate, and potash used in establishing this practice.

COUNTY	ITEM	EXTENT OF PRACTICES CARRIED OUT	TOTAL EST. COST TO GOV. INCLUDING ADM. EXPENSES
Sumner	1	None	None
	2	None	None
	3	(a) None	None
		(b) None	None
	4	None	None
	5	None	None
	6	78,000 ft.	$957.00
	7	65,901 cu. yds.	$7,183.00
	8	(a) 2,000 acres	$16,000.00 **
		(b) 84 acres	$1,264.00 **
	9	32 acres	$315.00 **
	10	None	None
	11	None	None
	12	None	None
	13	5 acres	$40.00

** Includes lime, phosphate, and potash used in establishing this practice.

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UNITED STATES DEPARTMENT OF AGRICULTURE
PRODUCTION AND MARKETING ADMINISTRATION

Lexington 29, Kentucky
April 18, 1950

To: Mr. H. K. Gayle, State Conservationist
Soil Conservation Service

From: Frank A. Taylor, Chief, Audit & Statistical Section
Production and Marketing Administration
/s/ Frank A. Taylor

Subject: Flood Control Survey, Green River Basin

In accordance with our discussion on April 5, this office has prepared a tabulation showing the total amount of payments this office has made for certain conservation measures. You will note that we did not tabulate any information with respect to the following:

1. Tributary channel improvement and streambank stabilization,

2. Erosion control along roads and railroads,

3. Perennial vegetation (such as, Alfalfa-Grass),

4. Sub-watershed waterways, and

5. Wildlife area improvement.

The Production and Marketing Administration did not make any payments in these counties for any practice that could be classified under the above headings.

In making this tabulation we have taken into consideration the administrative costs in the counties and the State administrative costs. As you know we have certain priority practices in Kentucky and we took these into consideration when we made the tabulation.

Since our 1949 figures are not yet available, we used the 1947 data as we believe it is more representative than the 1948.

If you desire any additional information in regard to this tabulation, please do not hesitate to ask us, as we are always anxious and willing to cooperate with you on any project.

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SUMMARIZED INFORMATION SUBMITTED
BY KENTUCKY P&MA ON GREEN RIVER

Practice	ACP Payments
Gully Stabilization	$ 34
Tile Drainage 1/	1,228
Open Ditches 1/	14,616
Diversion Ditches	2,032
Terracing	5,797
Farm Ponds	28,682
Pasture Improvement	1,163,138
Water Disposal	501

1/ These practices were not used in this report.

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TELEPHONE CONVERSATIONS WITH FRANK TAYLOR
LEXINGTON, KENTUCKY, P&MA 4/20/50

Taylor said administrative costs were computed on the ratio of $237,734 (administrative county and state level costs in watershed) to $4,765,000 (total costs in watershed). (Amounts to 5 percent administrative costs.)

Oren told Taylor that SCS could apply ACP unit payments to P&MA chart figures to determine amounts of each practice reported except pasture improvement. Taylor was requested to give SCS number of acres of pasture improvement accomplished by 1947 payment of $1,163,138 in watershed for lime, phosphate, potash and seed for pastures.

Taylor called back and reported this represented 279,505 acres of pasture. The average payment was $4.16 per acre.

Tentative Application of Above Information

An administrative cost of 5 percent was added to 1947 ACP unit payments. This figure was divided into the total amount of money reported for each practice. The resulting figure is the annual rate of application of that practice. For example: To the unit payment of $1.00 per hundred feet for terracing, an administrative cost of 5 cents was added. $5,797 (total payments for terracing) was divided by $1.05 giving 552,000 feet as the average annual rate of terracing in the P&MA going program.

Table E-1

DISTRIB ASSES

Land Use		Unit		VII	TOTAL
Cropland[1/]	Present	Ac.		70,154	1,532,538
	Recommended	Ac.	2/	32,206[2/]	1,539,297
	Net Change	Ac.		-37,948	+6,759
Woodland	Present	Ac.		1,048,450	1,985,528
	Recommended	Ac.		1,205,723	2,151,465
	Net Change	Ac.		+157,273	+165,937
Idleland	Present	Ac.		193,580	623,400
	Recommended	Ac.		0	0
	Net Change	Ac.		-193,580	-623,400
Pasture	Present	Ac.		255,701	1,496,762
	Recommended	Ac.		329,956	1,947,466
	Net Change	Ac.		+74,255	+450,704
	Sub-Total	Ac.		1,567,885	5,638,228
	Miscellaneous	Ac.			296,492
	TOTAL	Ac.			5,934,720

1/ Includes Deep-Rooted Perennia

2/ Deep-Rooted Perennials and Wi

Table E-1

DISTRIBUTION OF LAND SHOWING PRESENT, RECOMMENDED, AND NET CHANGE IN LAND USE BY CAPABILITY CLASSES
GREEN RIVER WATERSHED IN KENTUCKY AND TENNESSEE

Land Use		Unit	I	II	IIA	III	IIIA	IV	IVA	VI	VII	TOTAL
Cropland1/	Present	Ac.	68,340	509,323	244,661	408,601	36,416	143,880	6,190	44,973	70,154	1,532,538
	Recommended	Ac.	86,275	566,801	203,501	449,812	0	177,003	0	23,699 2/	32,206 2/	1,539,297
	Net Change	Ac.	+17,935	+57,478	-41,160	+41,211	-36,416	+33,123	-6,190	-21,274	-37,948	+6,759
Woodland	Present	Ac.	10,978	173,041	143,132	204,930	46,828	162,293	19,548	176,338	1,048,450	1,985,528
	Recommended	Ac.	10,978	173,041	143,132	204,930	46,828	162,293	19,548	185,002	1,205,723	2,151,465
	Net Change	Ac.	0	0	0	0	0	0	0	+8,664	+157,273	+165,937
Idleland	Present	Ac.	1,114	71,667	56,788	111,668	16,718	102,710	4,096	65,059	193,560	623,400
	Recommended	Ac.	0	0	0	0	0	0	0	0	0	0
	Net Change	Ac.	-1,114	-71,667	-56,788	-111,668	-16,718	-102,710	-4,096	-65,059	-193,580	-623,400
Pasture	Present	Ac.	18,804	327,272	82,845	369,991	23,361	257,255	6,644	154,889	255,701	1,496,762
	Recommended	Ac.	1,983	341,461	180,793	440,448	76,495	326,842	16,930	232,558	329,956	1,947,466
	Net Change	Ac.	-16,821	+14,189	+97,948	+70,457	+53,134	+69,587	+10,286	+77,669	+74,255	+450,704
	Sub-Total	Ac.	99,236	1,081,293	527,426	1,095,190	123,323	666,138	36,478	405,259	1,567,885	5,638,226
	Miscellaneous	Ac.										296,492
	TOTAL	Ac.										5,934,720

1/ Includes Deep-Rooted Perennials and Wildlife.
2/ Deep-Rooted Perennials and Wildlife only.

Table E-2

PRENITS

		MISCELLANEOUS 4/	TOTAL
Pennyroyal	Present	146,159	2,829,440
	Recommen	146,159	2,829,440
	Net Chan	0	0
Western Coal Field	Present	150,333	3,105,280
	Recommen	150,333	3,105,280
	Net Chan	0	0
Total Watershed	Present	296,492	5,934,720
	Recommen	296,492	5,934,720
	Net Chan	0	0

1/ Includes orchards.
2/ Includes rotated pastur
3/ Includes water disposal
4/ Farm home sites, urban

Table E-2

Table E-2

PRESENT AND RECOMMENDED LAND USE SHOWING NET CHANGES IN LAND USE ACRES BY PHYSICAL LAND UNITS
GREEN RIVER WATERSHED IN KENTUCKY AND TENNESSEE

		CROPLAND 1/	PASTURE 2/	DEEP ROOTED PERENNIALS 3/	WOODLAND	WILDLIFE	IDLE	MISCELLANEOUS 4/	TOTAL
Pennyroyal	Present	725,042	833,377	45,380	838,950	1,410	239,122	146,159	2,829,440
	Recommended	688,255	1,028,749	98,098	860,233	7,946	0	146,159	2,829,440
	Net Change	-36,787	+195,372	+52,718	+21,283	+6,536	-239,122	0	0
Western Coal Field	Present	753,250	663,385	7,280	1,146,578	176	384,278	150,333	3,105,280
	Recommended	628,724	918,717	102,062	1,291,232	14,212	0	150,333	3,105,280
	Net Change	-124,526	+255,332	+94,762	+144,654	+14,036	-384,278	0	0
Total Watershed	Present	1,478,292	1,496,762	52,660	1,985,528	1,586	623,400	296,492	5,934,720
	Recommended	1,316,979	1,947,466	200,160	2,151,465	22,158	0	296,492	5,934,720
	Net Change	-161,313	+450,704	+147,500	+165,937	+20,572	-623,400	0	0

1/ Includes orchards.
2/ Includes rotated pasture.
3/ Includes water disposal areas.
4/ Farm home sites, urban areas, roads, streams, etc.

Table E-3

S D, AND

Measures	Recommended Program		
	...oyal	Western Coal Field	Total
Group 1 Measures			
1. Sub-Watershed Water...	...400	2,100	3,500
2. Farm Waterways	...200	6,100	12,300
3. Terracing	...900	49,700	110,600
4. Diversions	...400	2,000	5,400
5. Gully Stabilization	...500	3,900	4,400
6. Road Bank Stabiliza...	...400	4,000	6,400
7. Railroad Bank Stabilization	30	200	230
8. Perennial Vegetation	...300	85,800	87,100
9. Pasture Development	...300	358,700	685,000
10. Farm Ponds	...800	15,800	22,600
11. Wildlife Area Development	...000	10,100	14,100
Group 2 Measures			
1. Tributary Channel Improvement and Stream Bank Stabilization	...100	1,600	2,700

Table E-3

SUMMARY OF WATERSHED NEEDS, ESTIMATED ACCOMPLISHMENTS OF GOING PROGRAMS FOR TWENTY-YEAR PERIOD, AND RECOMMENDED PROGRAM FOR OPEN LAND BY PHYSICAL LAND UNITS
GREEN RIVER WATERSHED

Measures	Unit	Watershed Needs			Going Program			Recommended Program		
		Pennyroyal	Western Coal Field	Total	Pennyroyal	Western Coal Field	Total	Pennyroyal	Western Coal Field	Total
Group 1 Measures										
1. Sub-Watershed Waterways	Mile	1,400	2,100	3,500	---	---	---	1,400	2,100	3,500
2. Farm Waterways	Acre	6,900	6,900	13,800	700	800	1,500	6,200	6,100	12,300
3. Terracing	Mile	65,100	51,000	116,100	4,200	1,300	5,500	60,900	49,700	110,600
4. Diversions	Mile	4,500	2,500	7,000	1,100	500	1,600	3,400	2,000	5,400
5. Gully Stabilization	Mile	500	3,900	4,400	---	---	---	500	3,900	4,400
6. Road Bank Stabilization	Mile	2,400	4,000	6,400	---	---	---	2,400	4,000	6,400
7. Railroad Bank Stabilization	Mile	30	200	230	---	---	---	30	200	230
8. Perennial Vegetation	Acre	42,300	93,500	135,800	41,000	7,700	48,700	1,300	85,800	87,100
9. Pasture Development	Acre	970,200	901,800	1,872,000	643,900	543,100	1,187,000	326,300	358,700	685,000
10. Farm Ponds	No.	13,000	21,200	34,200	6,200	5,400	11,600	6,800	15,800	22,600
11. Wildlife Area Development	Acre	6,500	14,000	20,500	2,500	3,900	6,400	4,000	10,100	14,100
Group 2 Measures										
1. Tributary Channel Improvement and Stream Bank Stabilization	Mile	1,100	1,600	2,700	---	---	---	1,100	1,600	2,700

Crops	Unit	Total	
		Present	Future
Tobacco: Burley	Ac.	61,608	61,608
Dark Air Cured	Ac.	14,401	14,401
Dark Fired	Ac.	2,435	2,435
Soybeans for Beans	Ac.	24,675	24,675
Truck and Vegetables	Ac.	47,513	47,513
Orchards, Vineyards, etc.	Ac.	20,938	20,938
Corn	Ac.	777,990	502,892
Small Grain for Grain: Oats	Ac.	32,021	46,982
Barley	Ac.	21,012	28,814
Wheat 2/	Ac.	138,530	192,258
Small Grain Hay	Ac.	2,572	---
Soybeans and Cowpea Hay	Ac.	58,047	50,091
Lespedeza Hay 3/	Ac.	175,876	219,680
Clover and Timothy Hay	Ac.	65,542	90,118
Other Tame and Wild Hay	Ac.	78,390	101,611
Seed: Lespedeza 4/	Ac.	18,157	27,396
Rotation Pasture	Ac.	1,029,140	575,089
Perennials, Deep Rooted 5/	Ac.	52,660	200,160
Permanent Pasture	Ac.	467,622	1,372,377
Cover Crops	Ac.	87,073	589,180
Combined Acreage: Rotation and Permanent Pasture	Ac.	1,496,762	1,947,466
Carrying Capacity of Grazing 1/ Crops in Beef Cows Producing Commercial Fat Calves	Brood Cows	521,384	905,716

1/ Estimated carrying capacity of grazi of the pasture productivity.
2/ Includes rye.
3/ Includes grass in future.
4/ Includes red clover.
5/ Includes water disposal areas.

Table E-4

ESTIMATED ACREAGE OF MAJOR CROPS, PRESENT AND FUTURE 1/
GREEN RIVER WATERSHED

Crops	Unit	Pennyroyal Area				Western Coal Field Area				Total	
		Eastern		Western		Sandstone-Shale		Loess			
		Present	Future	Present	Future	Present	Future	Present	Future	Present	Future
Tobacco: Burley	Ac.	28,178	28,178	17,220	17,220	8,792	8,792	7,418	7,418	61,608	61,608
Dark Air Cured	Ac.	1,266	1,266	3,270	3,270	1,432	1,432	8,433	8,433	14,401	14,401
Dark Fired	Ac.	---	---	207	207	2,228	2,228	---	---	2,435	2,435
Soybeans for Beans	Ac.	---	---	---	---	4,586	4,586	20,089	20,059	24,675	24,675
Truck and Vegetables	Ac.	16,021	16,021	8,299	8,299	18,128	18,128	5,065	5,065	47,513	47,513
Orchards, Vineyards, etc.	Ac.	6,257	6,257	3,751	3,751	7,970	7,970	2,960	2,960	20,938	20,938
Corn	Ac.	233,537	156,650	159,119	105,170	256,680	113,130	128,654	127,942	777,990	502,892
Small Grain for Grain: Oats	Ac.	12,279	22,250	10,584	11,198	6,608	11,296	2,550	2,238	32,021	46,982
Barley	Ac.	5,775	10,538	8,571	9,128	3,941	6,746	2,725	2,402	21,012	28,814
Wheat 2/	Ac.	35,660	64,794	41,815	44,408	35,402	60,402	25,653	22,654	138,530	192,258
Small Grain Hay	Ac.	838	---	405	---	555	---	774	---	2,572	---
Soybeans and Cowpea Hay	Ac.	4,733	---	3,223	---	35,105	35,105	14,986	14,986	58,047	50,091
Lespedeza Hay 3/	Ac.	68,320	76,696	18,353	40,715	69,303	87,707	19,900	14,562	175,876	219,680
Clover and Timothy Hay	Ac.	25,319	28,373	11,739	32,448	15,742	19,967	12,742	9,330	65,542	90,118
Other Tame and Wild Hay	Ac.	20,154	22,672	10,095	27,977	29,478	37,272	18,663	13,690	78,390	101,611
Seed: Lespedeza 4/	Ac.	1,612	1,814	5,989	16,607	2,370	2,958	8,186	6,017	18,157	27,396
Rotation Pasture	Ac.	286,744	147,643	296,123	136,183	333,918	136,566	112,355	154,697	1,029,140	575,089
Perennials, Deep Rooted 5/	Ac.	13,530	53,733	31,550	44,365	4,149	76,526	3,131	25,536	52,660	200,160
Permanent Pasture	Ac.	147,010	420,767	103,500	324,156	155,828	493,282	61,284	134,172	467,622	1,372,377
Cover Crops	Ac.	22,488	166,832	17,605	101,797	29,179	150,266	17,801	170,285	87,073	589,180
Combined Acreage: Rotation and Permanent Pasture	Ac.	433,754	568,410	399,623	460,339	489,746	629,848	173,639	288,869	1,496,762	1,947,466
Carrying Capacity of Grazing 1/ Crops in Beef Cows Producing Commercial Fat Calves	Brood Cows	150,180	286,124	153,075	252,982	144,034	227,895	74,095	138,715	521,384	905,716

1/ Estimated carrying capacity of grazing crops in beef cows producing commercial fat calves is inserted as an evaluation unit of the pasture productivity.
2/ Includes rye.
3/ Includes grass in future.
4/ Includes red clover.
5/ Includes water disposal areas.

Table E-5

AREA OF WOODLAND TO BE PROTECTED AGAINST FIRE
GREEN RIVER WATERSHED

Physical Land Unit, State, and Fire Hazard Zone	Ownership			Total
	National Forest	National Park	State and Private	
	Acres	Acres	Acres	Acres
Western Coalfield				
Kentucky				
High Hazard Zone	438,800	--	350,722	789,522
Medium Hazard Zone	--	45,000	456,710	510,710
Low Hazard Zone	--	--	--	--
Total	438,800	45,000	807,432	1,291,232
Pennyroyal				
Kentucky				
High Hazard Zone	--	--	138,168	138,168
Medium Hazard Zone	--	--	364,121	364,121
Low Hazard Zone	--	--	265,892	265,892
Total, Kentucky	--	--	768,181	768,181
Tennessee				
High Hazard Zone	--	--	69,824	69,824
Medium Hazard Zone	--	--	--	--
Low Hazard Zone	--	--	22,228	22,228
Total, Tennessee	--	--	92,052	92,052
Total, Pennyroyal	--	--	860,233	860,233
Total Watershed	438,800	45,000	1,667,665	2,151,465

Table E-6

AREA OF LAND TO BE PLANTED TO FOREST BY PHYSICAL LAND UNITS,
PLANTING INTENSITY, STATE AND OWNERSHIP
GREEN RIVER WATERSHED

Physical Land Unit, State, and Planting Intensity	Major Ownership Class			
	Federal	Other Public	Private	Total
	Acres	Acres	Acres	Acres
Western Coal Field				
Kentucky				
Full Planting (1,000 trees/acre)	61,297	323	138,612	200,232
Partial Planting (500 trees/acre)	53,063	289	119,978	173,330
Total Kentucky Western Coal Field	114,360	612	258,590	373,562
Pennyroyal				
Kentucky				
Full Planting (1,000 trees/acre)	--	386	173,392	173,778
Partial Planting (500 trees/acre)	--	346	150,100	150,446
Total Kentucky Pennyroyal	--	732	323,492	324,224
Tennessee				
Full Planting (1,000 trees/acre)	--	--	16,180	16,180
Partial Planting (500 trees/acre)	--	--	14,007	14,007
Total Tennessee Pennyroyal	--	--	30,187	30,187
Total Pennyroyal	--	732	353,679	354,411
Total Watershed	114,360	1,344	612,269	727,973

Table E-7

SUMMARY OF WATERSHED NEEDS AND RECOMMENDED PROGRAM
FOR FOREST LANDS BY PHYSICAL LAND UNITS 1/
GREEN RIVER WATERSHED

Measures	Unit	Watershed Needs			Recommended Program		
		Pennyroyal	Western Coal Field	Total	Pennyroyal	Western Coal Field	Total
Fire Control	Ac.	860,233	1,291,232	2,151,465	860,233	1,291,232	2,151,465
Forest Planting	Ac.	354,411	373,562	727,973	354,411	373,562	727,973
Land Acquisition	Ac.	--	438,000	438,000	--	438,000	438,000

1/ Estimated accomplishments of "going" programs insignificant.

FIG. E-I

PARTMENT OF AGRICULTURE
CONSERVATION SERVICE
H. H. BENNETT, CHIEF
UTHEASTERN REGION
BUIE, REGIONAL DIRECTOR

RIVER WATERSHED
IN
CKY AND TENNESSEE
SHOWING
CAL LAND UNITS

0 10 20 MILES

LEGEND

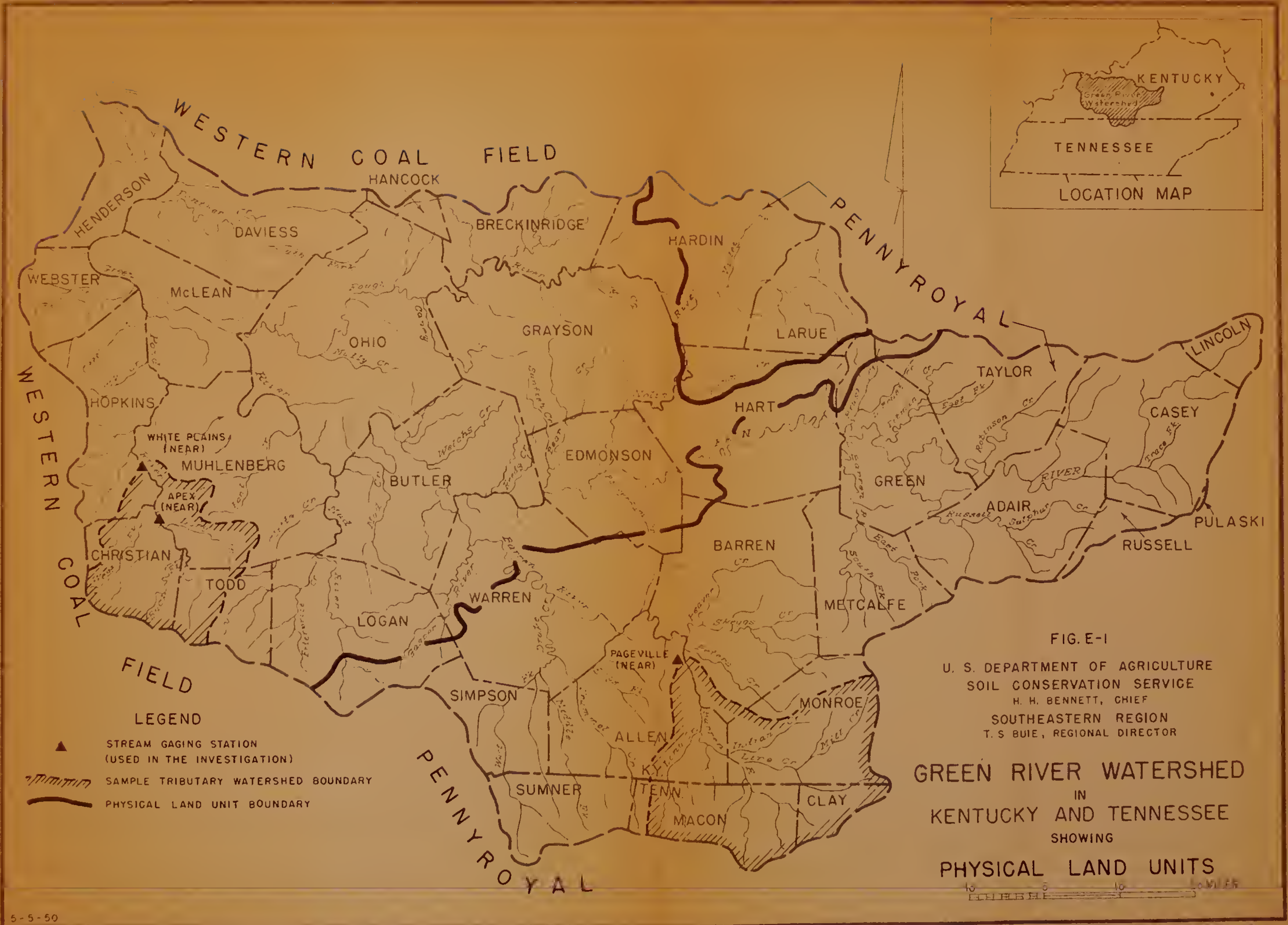
▲ STREAM GAGING STATION (USED IN THE INVESTIGATION)

SAMPLE TRIBUTARY WATERSHED

PHYSICAL LAND UNIT BOUNDARY

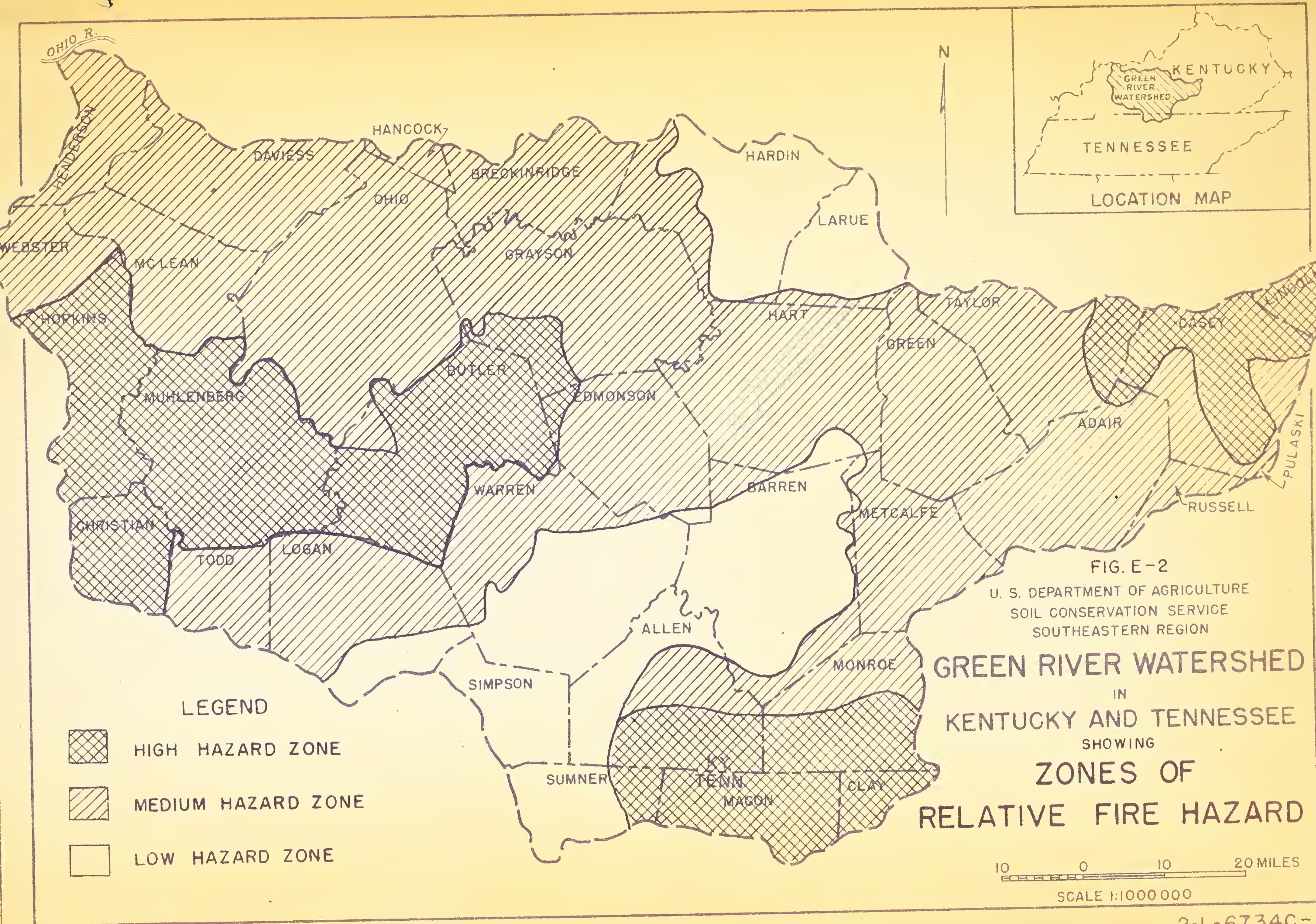
5-5-50

2-N-6145D-4


WESTERN COAL FIELD
PENNYROYAL
WESTERN COAL FIELD
PENNYROYAL
KENTUCKY
Green River Watershed
TENNESSEE
LOCATION MAP
HENDERSON
DAVIESS
HANCOCK
BRECKINRIDGE
HARDIN
WEBSTER
McLEAN
OHIO
GRAYSON
LARUE
TAYLOR
LINCOLN
HOPKINS
HART
CASEY
WHITE PLAINS (NEAR)
MUHLENBERG
BUTLER
EDMONSON
GREEN
APEX (NEAR)
ADAIR
PULASKI
RUSSELL
CHRISTIAN
TODD
BARREN
WARREN
LOGAN
METCALFE
PAGEVILLE (NEAR)
SIMPSON
MONROE
ALLEN
KY.
TENN.
SUMNER
MACON
CLAY
LEGEND
STREAM GAGING STATION (USED IN THE INVESTIGATION)
SAMPLE TRIBUTARY WATERSHED BOUNDARY
PHYSICAL LAND UNIT BOUNDARY
FIG. E-1
U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
H. H. BENNETT, CHIEF
SOUTHEASTERN REGION
T. S BUIE, REGIONAL DIRECTOR
GREEN RIVER WATERSHED
IN
KENTUCKY AND TENNESSEE
SHOWING
PHYSICAL LAND UNITS
5-5-50

2-N-6145D-4

FIG. E-2



2-L-6734C-1

FIG. E-3

FIG. E-3

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
SOUTHEASTERN REGION

GREEN RIVER WATERSHED
IN
KENTUCKY AND TENNESSEE
SHOWING
LAND ACQUISITION ZONE

2-L-67340-1